Environmental Studies No.60

Beaufort Environmental Monitoring Project 1987-1988 Final Report

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BEAUFORT ENVIRONMENTAL MONITORING PROJECT

1987-1988 FINAL REPORT

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PREFACE

The restricted objectives of the Beaufort Environmental Monitoring Project should be emphasized. The intent of the project is not to provide recommendations for a definitive research program which would address all the fundamental knowledge gaps that exist in the Beaufort region. The cost of acquiring these data would be very high and may still fail to address the issues that finally emerge as those of regulatory and public concern. The objective of BEMP is to identify and recommend those research and monitoring activities that are necessary for the responsible management of a phased development of Beaufort Sea hydrocarbons, through the administration of relevant legislation administered by INAC. The specific focus and objectives of BEMP should not detract from an overall recognition of our fundamental knowledge gaps in the Beaufort. Encouragement and support should be given to those agencies with responsibilities to conduct research programs which reflect their particular mandate in this region.

David P. Stone
Northern Environmental Protection Branch
Indian and Northern Affairs Canada

ACKNOWLEDGEMENTS

The Beaufort Environmental Monitoring Project relies on the cooperation and contributions of numerous scientists and managers from government, the oil industry, universities and consultings firms. Although workshops were not conducted as part of this year's BEMP activities, many individuals provided information that formed the basis of the Project Overviews contained in this report. The following individuals are given special thanks for their contributions:

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Bowhead whales	1 and 21	John Ford
White whales	2	Allison Peacock
Ringed and bearded seals	3, 4 and 5	Allison Peacock
Arctic cod	6	Patricia Vonk
Polar bears	7 and 8	Allison Peacock
Hydrocarbons and heavy metals	13	David Thomas
Anadromous fishes	14, 15, 16 and 17	Patricia Vonk
Dredging	19	David Thomas
Oil-based drilling muds	20	David Thomas

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RÉSUMÉ

Le projet de surveillance environnementale de la mer de Beaufort (PSEB) a été entrepris en 1983 par le ministère des Affaires indiennes et du Nord canadien et par le ministère de l'Environnement. Ce projet doit permettre d'obtenir les données techniques de base nécessaires pour concevoir, exécuter et évaluer un programme de recherche et de surveillance environnementales qui soit à la fois complet et justifiable. Ce programme mis en oeuvre parallèlement à l'exploitation graduelle des hydrocarbures dans la mer de Beaufort termine sa cinquième année. Ce rapport fait état des activités de recherche entreprises durant cette année et renferme des recommandation quant aux études environnementales qui pourraient être entreprises à l'avenir.

INTRODUCTION

The Beaufort Environmental Monitoring Project (BEMP) was initiated in 1983 by Indian and Northern Affairs Canada and Environment Canada. It is to provide the technical basis for design, operation and evaluation of a comprehensive and defensible environmental research and monitoring program to accompany hydrocarbon development in the Beaufort Sea, relative to the regulatory responsibilities of INAC and Environment Canada. BEMP was considered necessary because of: (1) environmental concerns regarding this development; (2) general uncertainties associated with Environmental Impact Assessment; and (3) the need for a research and monitoring plan that is fully integrated with activities associated with phased development within the region.

During the first two years of BEMP (1983-84 and 1984-85), the project involved interdisciplinary workshops where participants discussed all the impact hypotheses formulated in the initial year of the project (INAC and Environment Canada 1983, 1984). The last two years focussed primarily on evaluating impact hypotheses related to the effects of hydrocarbon development on bowhead whales and use of oil-base drilling muds in the Beaufort Sea. It was considered important to review these hypotheses because there were still concerns regarding the effects of industrial facilities and activities on the western Arctic population of bowhead whales and the possible environmental implications of the recent use of oil-based drilling mud formulations in Beaufort operations. Decreased emphasis on the remaining hypotheses was due to lesser concerns regarding other potential effects of development given the reduced level of industrial activity in the region in the past 3 years. Nevertheless, ongoing and new research relevant to all BEMP hypotheses continued to be reviewed as part of the project to ensure that it remains both adaptive and iterative. In addition, research of general interest was also reviewed to ensure that the project is capable of responding to changes in the hydrocarbon development scenario for the region that may require new impact hypotheses to be formulated.

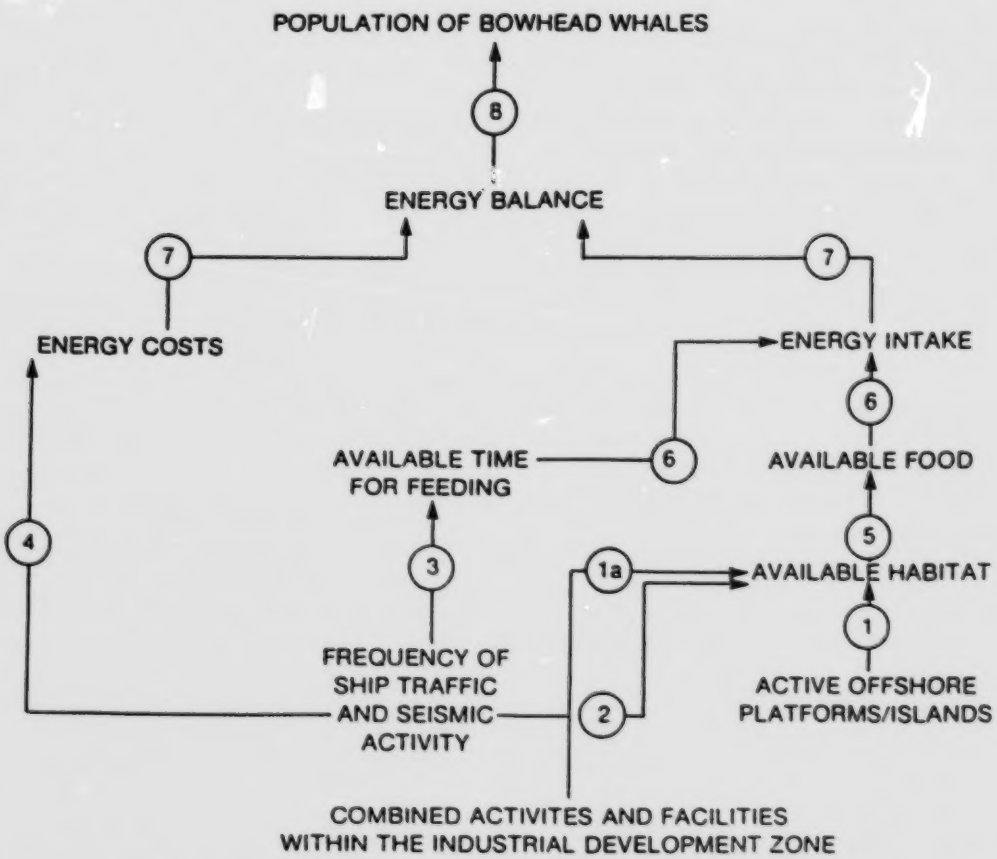
1987-1988 represents the fifth year of BEMP. The project involved reviewing the results of recent and ongoing studies as they have in past years to maintain continuity, and providing recommendations related to the future direction of the project. Evaluation of impact hypotheses through workshops was not considered essential because of the limited amount of new research relevant to the hypotheses initiated in the last year. The primary activities during 1987-1988 were: (1) a review of relevant studies initiated or completed since the last BEMP workshops in March 1987; (2) preparation of project overviews describing the purpose of these investigations and their relationship to existing BEMP hypotheses; and (3) evaluation of the overall status of knowledge regarding each hypothesis.

HYPOTHESIS NO. 1

Ship traffic, seismic exploration and active offshore structures will cause a reduction in the Western Arctic population of bowhead whales.

FIGURE 1-1

POTENTIAL EFFECTS OF SHIP TRAFFIC, SEISMIC EXPLORATION AND ACTIVE OFFSHORE STRUCTURES ON BOWHEAD WHALES



BEMP IMPACT HYPOTHESIS NO. 1

LINKAGES

1a. The cumulative effect of all offshore industry activities will be to create a large-scale zone of bowhead whale exclusion encompassing the entire industry zone.*

1. Each active offshore island or platform will exclude bowheads from a zone around the island/platform.

2. Ship traffic will exclude bowheads from a zone around the ship track.

3. Each passage of a ship will reduce the feeding time available to bowheads.

4. Each passage of a ship will increase the energy expenditure of whales due to avoidance behavior.

5. The available aquatic habitat determines the level of available food.

6. The amount of available food and the time available for feeding determine the energy intake.

7. Energy intake and expenditures determine the energy balance of a bowhead whale.

8. The energy balance of a bowhead whale determines its survival and its ability to reproduce.

* This hypothesis link was added to more clearly represent the emphasis on the possible cumulative impact of hydrocarbon development on bowhead whales.

BEMP IMPACT HYPOTHESIS NO. 1

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 1

Hypothesis No. 1 was re-evaluated during the 1986 workshop. The majority of the participants concluded that either the effect was possible but too difficult to detect, or the hypothesis was not testable. Notwithstanding this conclusion, several participants believed that there was a need to continue research on some critical links in the hypothesis. The discussion of research needs focussed on examination of the distribution of adequate bowhead feeding habitats within and outside the industry zone, particularly determination of the rates of use of zooplankton patches inside and outside this zone. The need for pre-established "stopping rules" and benefit-cost analysis prior to initiation of this research were also supported by many of the participants. Another recommendation of the group was refinement of hydroacoustic techniques to allow distinction of physical and biological targets.

Since the 1986 workshop, the bowhead whale food availability study (Project Overview 1-1) has been completed. Results of this study tend to add to the "weight of evidence" that the interannual variability in the distribution of bowhead whales in the southeastern Beaufort Sea is caused by responses to fluctuations in the distribution and abundance of food rather than behavioural responses to industrial activity.

REVIEW OF RECENT AND ONGOING RESEARCH PROJECTS

BEMP PROJECT OVERVIEW NO. 1-1

TITLE:	Bowhead Whale Food Availability Characteristics in the Southern Beaufort Sea: 1985 and 1986
PRINCIPAL INVESTIGATOR:	M. Bradstreet, D.H. Thomson and D.B. Fissel
AFFILIATION:	LGL Limited, King City, Ontario
FUNDING SOURCE:	INAC, NOGAP
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	1

BRIEF PROJECT DESCRIPTION

The primary objective of this study was to gain a better understanding of the importance of nearshore and adjacent marine waters between Cape Dalhousie and Herschel Island in the annual energy budget of the bowhead whale. It was designed to supplement the results of the 1985 study, "Food availability characteristics of the offshore Yukon coast to the bowhead whale" (discussed in INAC and Environment Canada 1986) by:

BEMP IMPACT HYPOTHESIS NO. 1

1. enlarging the sampling area to include the whole of the industrial zone and regions east of the industrial zone;

2. resampling the Yukon offshore area to allow inter-annual comparison of zooplankton densities; and

3. improving and expanding the use of hydroacoustic measurements to better estimate the total biomass and distribution of zooplankton available to bowhead whales in the southeast Beaufort Sea.

The study area in 1986 comprised the southern Beaufort Sea east of the Alaska-Yukon border including the Yukon offshore, an area approximately north of the Mackenzie Delta, and an area off the western Tuktoyaktuk Peninsula. The seaward boundary extended to about the 100 m depth contour. Field work was conducted from the 68-m icebreaker class II supply vessel Arctic Ivik during the period from 27 August to 08 September 1986. The following tasks were undertaken:

1. Sampling of zooplankton to determine their distribution, patchiness and total biomass using various net tows, a 200 kHz narrow-beam echo sounder, and sampling of the epibenthos;

2. A physical oceanographic characterization of the study area including temperature, salinity and turbidity profiles, infrared satellite sea-surface imagery and meteorological measurements; and

3. Analysis of the zooplankton prey found to be available to the bowheads including determinations of calorimetry, and lipid fractions.

In both years of the study, it was discovered that the distribution of zooplankton abundance in the southeast Beaufort Sea was related to the location of the Mackenzie River plume. Biomass was lowest in areas within the plume. In both 1985 and 1986, bowheads were observed feeding at locations where zooplankton biomass was high. Net samples in the vicinity of feeding whales revealed zooplankton concentrations in excess of 1 g/m^3, reaching maximum site-specific values of 2.3 g/m^3 (1985) and 1.5 g/m^3 (1986). It is suggested that the occurrence of concentrations of zooplankton in dense subsurface layers is more important to feeding bowheads than overall zooplankton abundance. In 1986, the distribution of bowheads was consistent with the hypothesis that whales tend to avoid areas within the Mackenzie plume, where zooplankton abundance is low. Technical difficulties prevented the collection of data on the relative occurrence of concentrated zooplankton patches in plume vs. non plume areas.

In 1985 and 1986, as well as other past years, many bowheads were observed feeding in nearshore waters off the Yukon coast. The copepod *Limnocalanus macrurus* was found to be the dominant species of zooplankton present, and may be very important to the feeding ecology of bowheads in the region. Most whales observed along the Yukon coast are subadults, and may feed in the area for several weeks. It is estimated that over a six-week period, they may consume about 26% of their annual energetic requirements.

BEMP IMPACT HYPOTHESIS NO. 1

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project provides information that is particularly relevant to Links 5, 6, 7, and 8 of Hypothesis No. 1, which relate to the apparent role of the southeast Beaufort Sea as an important feeding ground for bowheads during the months of August and September. Results of the study add to the "weight of evidence" regarding the validity of the two hypotheses that have been proposed to account for the interannual variability in distribution patterns of bowheads in the southeastern Beaufort Sea during 1980-1986. These are that: (1) whales may be avoiding the industrial zone as a behavioural response to industrial activity, and (2) they are responding to fluctuations in the distribution and abundance of food.

BEMP PROJECT OVERVIEW NO. 1-2

TITLE:	**Importance of the Eastern Alaskan Beaufort Sea to Feeding Bowheads**
PRINCIPAL INVESTIGATOR:	W. John Richardson
AFFILIATION:	LGL Limited, King City, Ontario
FUNDING SOURCE:	U.S. Minerals Management Service
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

Most individuals of the western Arctic population of bowhead whales spend the period from May or June to September or October in the Beaufort Sea. During this period, they are believed to consume most of the food required for the entire year. Bowheads, like other baleen whales, are expected to consume little food in summer, although some winter feeding in the Bering Sea has been suggested by other researchers (Don Schell, University of Alaska). Nevertheless, the Beaufort Sea is clearly of critical importance in the annual energy budget of the majority of the Western Arctic population of bowhead whales.

The general purpose of this two-year project was to quantify the proportion of the energy requirements of the Western Arctic bowhead whale stock that is provided by food resources located in the eastern Alaskan Beaufort Sea from longitude 144°W east to the eastern edge of the zone whose jurisdiction is in dispute between the U.S.A. and Canada. The study area extended from the coast of northeastern Alaska north to latitude 71°30'N.

BEMP IMPACT HYPOTHESIS NO. 1

The specific objectives of the study were to:

1. determine the concentration and distribution of the planktonic food of bowhead whales in the eastern Alaskan Beaufort Sea and correlate these with known oceanographic features;

2. estimate the number of bowhead whales utilizing the eastern Alaskan Beaufort Sea as a feeding area during the summer and fall, and to observe and document their feeding activities, behaviour and residence times; and

3. estimate the degree of utilization of available food resources in the eastern Alaskan Beaufort Sea by the Western Arctic bowhead whale stock.

Field work for this project was conducted during September and early October of 1985-86. Water masses in the study area were studied by boat-based sampling and by airborne and satellite remote sensing. Zooplankton composition, biomass, distribution, patchiness, and energy content were documented by boat-based net and hydroacoustic sampling. Maximum zooplankton biomass was generally in one or more thin layers in the 8-40 m depth zone. Biomass was usually low in near-surface waters and decreased with increasing distance from shore. Zooplankton biomass was dominated by copepods. The highest biomasses of zooplankton, mainly the small copepod Limnocalanus macrurus, were found near bowheads feeding in nearshore waters in early September, 1986.

Aerial surveys were used to determine the distribution, numbers and activities of bowhead whales. Sizes of whales and the recurrence of identifiable individuals in feeding areas were documented with aerial photogrammetry. In addition, five bowheads were radio-tagged in 1986. Fewer whales were sighted in the study area in 1985 than in 1986, which was considered a more typical year. Prior to the onset of the westward migration, many subadult bowheads fed along the Yukon shore, but relatively few were present to the west within the study area. By mid September in both years, both adult and large subadult whales fed in the middle-shelf portion of the study area.

The study concluded that the western Arctic bowhead population acquired a low percentage of its total annual food and energy needs within the study area - probably <1% in 1985 and about 1.4% in 1986. Although some feeding is done by most whales that migrate through the eastern Alaskan Beaufort Sea, few remain there long enough to acquire a significant amount of food.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project is of considerable importance to Hypothesis No. 1, primarily through its relevance to Links 5-8. The study provides information which lends support to the hypotheses that the distribution of bowhead whales is controlled

by oceanographic factors that influence the distribution of their food. The research is also relevant to Links 1-3 in Hypothesis No. 21 in terms of the energy intake and balance of bowhead whales.

BEMP PROJECT OVERVIEW NO. 1-3

TITLE:	Prediction of Drilling Site-specific Interaction of Industrial Acoustic Stimuli and Endangered Whales in the Alaskan Beaufort Sea.
PRINCIPAL INVESTIGATORS:	P.R. Miles, C.I. Malme, W.J. Richardson
AFFILIATION:	BBN Laboratories Inc., Cambridge, MA; LGL Limited, King City, Ontario
FUNDING SOURCE:	U.S. Minerals Management Service
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

The overall purposes of this study were to describe the underwater acoustic environment and sound propagation characteristics of offshore oil drilling sites in the Alaskan Beaufort Sea and, using this information, to predict the ranges at which the behaviour of bowhead and gray whales is likely to be influenced by industrial noise emanating from these sites. The specific objectives of the study were to:

1. measure the acoustic environment prior to the onset of industrial operations;

2. measure underwater sound propagation loss (transmission loss) in the area of existing and planned offshore industry sites;

3. monitor and record sounds associated with offshore drilling sites; and

4. synthesize results of the above with data and/or models of bowhead and gray whale responses to underwater sounds.

The 1985 and 1986 field programs obtained acoustic measurements at six selected offshore sites, including the natural ambient noise characteristics, acoustic signatures of noise associated with drillsite activities, sound speed profiles, and acoustic transmission loss characteristics at various ranges from each site. It was found that sound attenuates less rapidly with increasing distance in the Beaufort Sea than in many other areas. Two acoustic criteria were used to relate industrial noise levels to whale behavioural response. These were (1) predicted signal-to-noise ratio (S:N) in the 1/3-octave band of highest

S:N, and (2) absolute received sound pressure level in either that same 1/3-octave band or in the overall effective bandwidth of the signal. Both were used in developing behavioural response predictions since it is not known whether S:N or absolute noise level is more important in eliciting responses by whales.

It was expected that roughly half of the bowheads would respond to underwater noise when the S:N (industrial noise to ambient noise ratio) is 30 dB. At the sites investigated, this S:N condition is expected to occur at 1.6 to 12 km from two tugs holding a barge against a gravel island, 1 to 4 km from a drillship drilling, and 0.02 to 0.2 km from drilling on an artificial island. Similar zones of responsiveness were predicted using the absolute level criterion.

The actual zone of audibility of industrial noise, within which the industrial noise level is equal or exceeds the ambient level (S:N = 0 dB), is much larger than the zones of responsiveness. Zones of audibility are predicted to vary from 21 km to >50 km, depending on the site, under median ambient conditions. Behavioural changes in the outer portions of the zones of audibility are expected to be very subtle.

The study also considered the potential effects of industrial noises that are intermittent or fluctuate in level over time. Examples of these noise sources are icebreakers working on ice at drillsites, dredge operations and short-term operations of a tug towing a loaded barge. Although no specific data on responses of whales to this type of source were available, it was assumed (1) that whales respond similarly to man by reacting to an average of the fluctuating acoustic energy over a finite period of time, and (2) that whales respond to the highest short term signal level in the same way as they do to continuous noise. Of the intermittent sound sources considered, peak levels of noise radiated by a working icebreaker are the most intense. For that source, the zones of responsiveness vary from 4.6 to 12 km for the first assumption and from 19 to 34 km based on the second assumption.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project is of direct relevance to Hypothesis No. 1, which states that "Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales", as well as the new hypothesis concerning the proposal to transport early Beaufort production to the west by shuttle tanker during the open-water season (Hypothesis No. 21). The study specifically addresses Link 1 of Hypothesis No. 1, which suggests that "each active offshore island or platform will exclude bowheads from a zone around the island-platform", as well as Links 2, 3 and 4. Although the acoustic data resulting from the study are restricted to sites in Alaska, they will be useful in predicting zones of influence of industry activity in the Canadian Beaufort where similar acoustic conditions may be expected.

BEMP IMPACT HYPOTHESIS NO. 1

BEMP PROJECT OVERVIEW NO. 1-4

TITLE:	**Responses of Bowhead Whales to an Offshore Drilling Operation in the Alaskan Beaufort Sea, Autumn 1986.**
PRINCIPAL INVESTIGATORS:	R.A. Davis and C.R. Greene
AFFILIATION:	LGL Limited, King City, Ontario; Greeneridge Sciences Inc., Santa Barbara, CA
FUNDING SOURCE:	Shell Western E and P Inc.
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

The purpose of this study was to determine the reaction of bowhead whales to the presence of an offshore drilling operation in their fall migration path in the Alaskan Beaufort Sea. The basic approach of the study was to use aerial observation and underwater acoustic monitoring to document the behavioural responses of bowheads to varying noise levels as the whales approached drilling operations at the Corona and Hammerhead drillsites during autumn, 1986. These observations were compared to behavioural data from undisturbed bowheads outside the potential range of influence of the drilling operation.

Systematic aerial surveys were undertaken to determine the location of migrating whales in relation to the drilling operation. When whales were found in the study area, behavioural responses such as duration of surfacing and dives, respiration (blow) intervals, and number of blows per surfacing were recorded and aerial photographs were taken to determine their lengths and, in some cases, their individual identities as revealed by pigmentation patterns and scars. Sonobuoy hydrophones were also deployed to monitor underwater noise spectra and levels in the vicinity of the whales.

In addition to aerial observations, hydrophone arrays were established near the Corona and Hammerhead drillsites to measure temporal variations in frequencies and received levels of industrial and natural ambient noise. These arrays were also used to detect and localize bowheads by monitoring their underwater calls.

The most important finding of this study was that migrating bowheads appeared to avoid the offshore drilling operation. No whales were located closer than 9.5 km from the drillship, and few bowheads were sighted closer than 15 km. However, significant numbers of whales were observed to pass to the south (inshore) and north (offshore) of the drillsite. Bowheads found 15-30 km from the drillship were observed on several occasions, but few exhibited noticeable behavioural responses. Apparently, the whales were avoiding closer approach to the drilling operation where stronger behavioural reactions might be expected.

BEMP IMPACT HYPOTHESIS NO. 1

Bowheads were observed to take evasive actions when approached by ships, as has been documented previously in the Canadian Beaufort Sea. Response levels were typical of these earlier observations. Reactions to operating seismic ships appeared to depend on range and direction of movement of the ship. Whales were seen to respond strongly to one seismic ship at longer ranges (24-22 km) than previously observed.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is directly relevant to Hypothesis No. 1, which states that "Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales". Results lend support to Link 1 of this hypothesis that there is a zone around active offshore drill rigs that bowheads tend to avoid. This study also provides information relevant to Link 6 of Hypothesis No. 21, which states that "tanker traffic will cause a long-term offshore displacement of the fall migration of bowheads off Alaska". Despite the observation that whales avoided the drillsite, this avoidance did not appear to act as a barrier to their fall migration. Bowheads passed to the north and south of the drillship, and this had no apparent effect on the timing of the migration. The presence of the drilling operation also had no apparent adverse impact on the Alaskan Eskimo bowhead hunt, as the fall hunt in 1986 was the most successful in recent years.

BEMP PROJECT OVERVIEW NO. 1-5

TITLE:	**Aerial Surveys of Endangered Whales in the Beaufort Sea: Fall 1987**
PRINCIPAL INVESTIGATOR:	Stephen B. Treacy
AFFILIATION:	U.S. Minerals Management Service
FUNDING SOURCE:	U.S. Minerals Management Service
EXPECTED COMPLETION DATE:	Late 1988
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

The purpose of this study was to document the relative abundance, distribution and migration timing of bowhead whales in the Alaskan Beaufort Sea during the late summer and fall of 1987. The location of the study and its methodology were similar to those in previous years. Results of the study were not available for inclusion in this review.

BEMP IMPACT HYPOTHESIS NO. 1

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study provides information on the occurrence and activities of bowheads in Alaskan waters that is relevant to Hypothesis No. 1. Data on the extent of feeding activity during the late summer in Alaska and the timing of fall migration will lead to a better understanding of the factors influencing the distribution of bowheads throughout the Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 1-6

TITLE:	Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea
PRINCIPAL INVESTIGATOR:	C.R. Greene
AFFILIATION:	Greeneridge Sciences Inc., Santa Barbara, CA
FUNDING SOURCE:	U.S. Minerals Management Service
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

This study summarizes research on the acoustic properties of oil industry dredge and drilling sounds conducted in the Canadian Beaufort Sea during August, 1980-84. The data on which this study is based can be found in various unpublished reports prepared by LGL Limited and Greeneridge Sciences Inc. for the U.S. Minerals Management Service, and have been discussed in previous BEMP workshops. The following is the abstract of the study report (Greene, C.R. Jr. 1987. Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. J. Acoust. Soc. Am. 82(4):1315-1324):

As part of a general study of underwater industrial noises and their effects on bowhead whales, sounds from drilling and dredging operations were measured in the shallow waters (<50 m) of the Canadian Beaufort Sea during August of each year from 1980-1984. The measurements were made from a vertical string of hydrophones at depths of 3, 9, and 18 m suspended from a sparbuoy. Sound sources included drillships logging and drilling, drilling at a caisson-retained island, transfer dredges, and hopper dredges. Results are presented in spectrum graphs, as sound pressure levels in their-octave and octave bands, and as overall levels in the 20- to 1000-Hz band. Most energy from these sources was below 1000 Hz. The weakest drilling/dredging sounds measured came from a drillship performing logging operations (122-125 dB re: 1μPa, 20-1000 Hz, range 0.17 km). The strongest sounds came from a hopper dredge underway with a damaged propeller (150 dB, range 0.46 km). Measured data were used to derive regression equations for received sound level versus range. In these shallow waters, the overall

noise (20- to 1000-Hz band) from most drilling and dredging operations would be at levels below the median ambient noise (99 dB) at ranges greater than 30 km.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project provides a summary of information that is useful in evaluating the validity of Hypothesis No. 1, particularly as it relates to the effects of noise associated with offshore industrial activities on the western population of bowhead whales. These acoustic data will be useful in predicting zones of influence of industrial activity in the Canadian Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 1-7

TITLE:	**Summer Distribution of Bowhead Whales, *Baleana mysticetus*, Relative to Oil Industry Activities in the Canadian Beaufort Sea, 1980-84.**
PRINCIPAL INVESTIGATOR:	W. John Richardson
AFFILIATION:	LGL Limited, King City, Ontario
FUNDING SOURCE:	U.S. Minerals Management Service
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

This study is a summary of information on the distribution of bowheads relative to oil industry operations in the Canadian Beaufort Sea during the summers of 1980-84. The information upon which this study is based can be found in a number of unpublished reports prepared by several organizations, and most of this has been reviewed in previous BEMP meetings.

The following is the abstract of the published report of this study (Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. Arctic 40(2):93-104.):

Aerial surveys in 1980-84 showed that summer distribution of bowheads in the Beaufort Sea varied markedly between years. Distribution varied both outside and within the "main industrial area" (MIA), the area of island construction, drilling and intensive ship and helicopter traffic. Numbers of bowheads in the MIA were high in 1980, lower in 1981, near zero in 1982 and very low in 1983-84. The few whales in the MIA in 1983-84 were mainly near its edges, contrary to 1980-81. These data, plus limited evidence from 1976-79, indicate that bowheads were numerous in the centre of the MIA in 3 of 5 years from 1976-80

(1976-77, 1980) vs. 0 of 4 years from 1981-84. One hypothesis is that progressively increasing industrial activities affected bowhead distribution after 1980. However, bowheads probably also react to variations in their zooplankton prey, which may be affected by year-to-year changes in oceanography and weather. Influences of natural factors on zooplankton and bowheads need to be better understood in order to assess whether oil exploration caused any of the observed changes in bowhead distribution.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is relevant to Hypothesis No. 1, which states that "ship traffic, seismic exploration and active offshore structures will cause a reduction in the western arctic population of bowhead whales". Although the review provides some evidence that the distribution of bowheads in the Canadian Beaufort Sea was influenced by industrial activities during 1981-1984, the authors report that more information on natural factors affecting zooplankton and bowhead distributions is required. Regional and local variations in food availability within the region may play a major role in the spatial distribution of at least some component of the bowhead population.

BEMP PROJECT OVERVIEW NO. 1-8

TITLE:	Population Length Structure and Recruitment in the Bowhead Whale derived from Aerial Photogrammetry, Spring 1985-1986.
PRINCIPAL INVESTIGATOR:	M.K. Nerini, D.E. Withrow, and K. Strickland
AFFILIATION:	National Marine Mammal Laboratory, National Marine Fisheries Service
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. Dec. 5-9, 1987, Miami, Florida.
RELEVANT BEMP HYPOTHESIS NO.:	1

BRIEF PROJECT DESCRIPTION

The following is the abstract which appears in the Seventh Biennial Conference on the Biology of Marine Mammals Abstracts, December 1987.

Aerial photographs of bowhead whales were taken in the spring of both 1985 and 1986 in the vicinity of Point Barrow, Alaska. The total lengths of 543 whales in 1985 and 234 whales in 1986 were measured. The measurement precision was estimated by using multiple images of the same whale (n=121) and appears to be in the order of 1.5% of the total body length.

BEMP IMPACT HYPOTHESIS NO. 1

Migrating whales are temporally segregated such that small animals travel early in the migration and cows accompanied by calves comprise the later migrants. Calves comprised 1.1% of the 1985 and 16.4% of the 1986 non-calf sample. Mature animals (> 13 m) represented 41.9% of the 1985 sample and 58.9% of the 1986 sample. The length distribution differed significantly between the two years which we attributed to a difference in the timing of the two field seasons and the size segregation in migrants.

The low proportion of calves in 1985 reappears as a small proportion of yearlings in 1986 suggesting that 1985 was a year of poor recruitment and that recruitment may vary widely between years. We suggest this marked variation may be driven by the availability of food resources in the Beaufort Sea in the summer and examine previous records of calf production in this population. Using a calving interval of 3 years by analogy with other right whales, we calculated a gross annual reproductive rate of 0.065 and 0.092 for 1985 and 1986, respectively.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is indirectly relevant to Hypothesis No. 1, which states that "ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales". The research is conducted in Alaska, but the distributional information, estimates of reproductive rates and methodological approach may aid in the assessment of this hypothesis.

BEMP PROJECT OVERVIEW NO. 1-9

TITLE:	**The Relationship Between Bowhead Whale Distribution and the Oceanography of Northern Seas.**
PRINCIPAL INVESTIGATOR:	G.A. Borstad, M.R. MacNeill
AFFILIATION:	G.A. Borstad Associates Ltd.
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. Dec. 5-9, 1987, Miami, Florida.
RELEVANT BEMP HYPOTHESIS NO.:	1 and 21

BRIEF PROJECT DESCRIPTION

The following is the abstract that appears in the Seventh Biennial Conference on the Biology of Marine Mammals Abstracts, December 1987.

The historical distribution of bowhead whales (*Balaena mysticetus*) was

compared with available environmental data, derived primarily from satellite images and ice reconnaissance charts.

Analysis suggests that bowhead behaviour at long-time scales is linked to regional ice conditions. In 1974, 1976, and 1984 large numbers of whales were observed feeding in the vicinity of Point Barrow. Heavy ice conditions in the eastern Alaskan Beaufort during the first week of September seemed to cause an early departure and the possibility of feeding at Barrow if conditions are suitable there. Large areas of open water in the east allow more feeding in the vicinity of Barter Island, and the end of migration is strongly correlated with accumulated freezing degree days.

Because of large annual variations in the timing and geographic nature of break-up and the duration and extent of open water, bowheads may find alternative feeding grounds away from the industrial areas in the southern Beaufort, either along Banks Island and in M'Clure Strait, or in Amundsen Gulf. Variations in ice cover probably mean that they cannot summer in the same area every year.

At smaller scales, thermal satellite images of the Barrow area on September 23, 1984 show that whales congregated near a strong frontal boundary where bird distribution suggest that zooplankton was especially abundant. Wider examination has also shown highly significant correlation between temperature fronts and bowhead distribution in the Canadian Beaufort, although this is not consistent presumedly because of biological and physical differences between fronts.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study was conducted in Alaska and is, therefore, only indirectly relevant to Hypotheses No. 1 and 21.

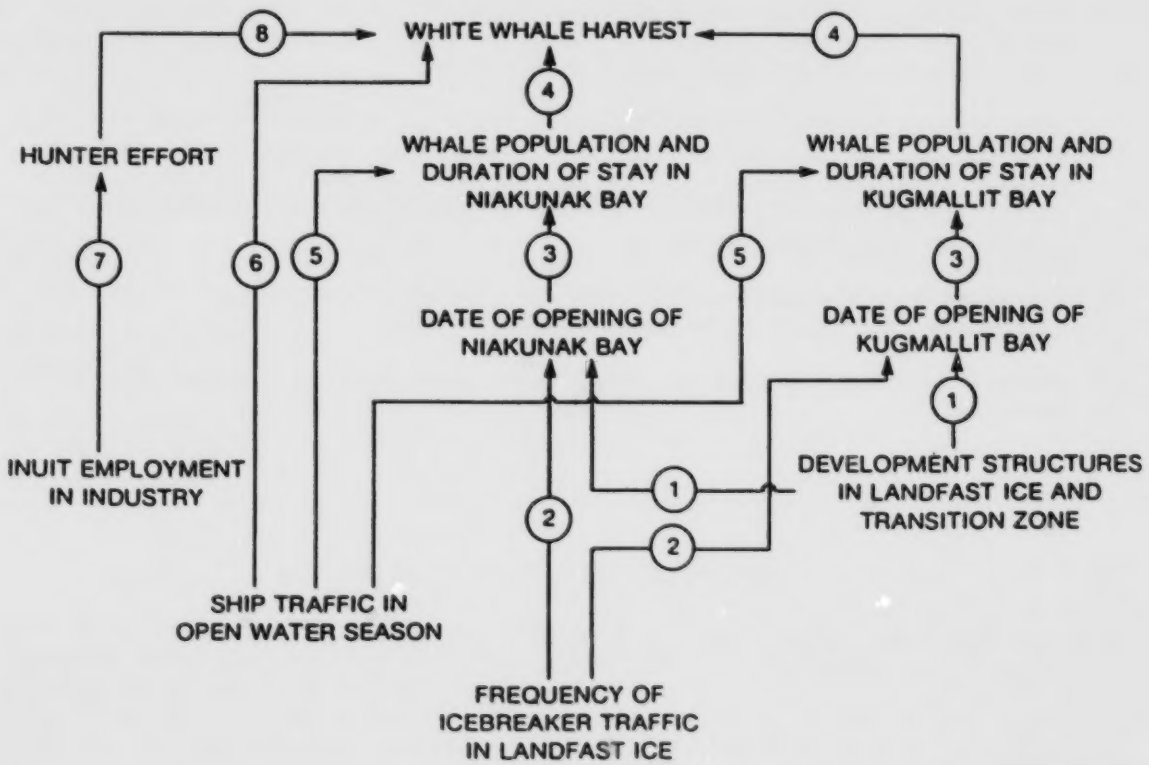
While it has been observed that the summer range of bowhead whales in the Beaufort Sea has varied from year to year, the factors controlling their distribution remain unknown. Few bowhead whales have been seen in the industrial zone since 1980, and it has been postulated that they have been excluded from an important feeding area due to disturbance from industry activities. Alternatively, it has been suggested that the distribution of bowhead whales is influenced by oceanographic factors that affect the abundance and distribution of food resources. The distributional and oceanographic data provided by this research may assist in the evaluation of these two hypotheses.

HYPOTHESIS NO. 2

A - Offshore structures will reduce the white whale harvest; B - Frequent icebreaker traffic in landfast ice will increase the white whale harvest; C - Open water ship traffic in the Mackenzie Estuary will alter white whale distribution and lead to changes in harvest levels.

FIGURE 2-1

THE EFFECTS OF VARIOUS FACILITIES AND ACTIVITIES ASSOCIATED WITH OFFSHORE HYDROCARBON DEVELOPMENT ON THE WHITE WHALE HARVEST



BEMP IMPACT HYPOTHESIS NO. 2

LINKAGES

1. Artificial islands off the Mackenzie Delta will delay the regional break-up of landfast ice.

2. Icebreaker traffic in the landfast ice in spring will advance the break-up of ice barriers across Kugmallit and Niakunak bays.

3. The timing of break-up of the landfast ice influences the timing of entry, and the numbers and the duration of residence of white whales in Niakunak and Kugmallit bays.

4. The numbers and the duration of residence of white whales in Kugmallit and Niakunak bays will influence the white whale harvest.

5. Ship passages through Niakunak and Kugmallit bays will disturb white whales, and this will reduce the number of animals that frequent the bays and/or the time that whales spend in the bays.

6. Ship traffic in Niakunak and Kugmallit bays will lead to changes in the distribution of whales in the bays, and these changes will lead to changes (probably reductions) in the harvest levels. In addition, ship traffic could directly interfere with hunting activities by frightening whales that are being hunted.

7. Increased Inuit employment by the oil industry and various supporting businesses will lead to changes in hunter effort.

8. Changes in hunter effort and experience will lead to changes in white whale harvest.

BEMP IMPACT HYPOTHESIS NO. 2

STATUS OF KNOWLEDGE REGARDING BEMP IMPACT HYPOTHESIS NO. 2

During the last workshop that involved re-evaluation of Hypothesis No. 2 (1985), participants confirmed the validity of this hypothesis but concluded that less emphasis should be placed on several of its linkages. In particular, the group expected that delayed ice break-up due to the presence of offshore artificial islands and advanced break-up as a result of icebreaker traffic were both unlikely under the present development scenario. Similarly, it was concluded that the present level of ship traffic is unlikely to prevent white whales from entering the Mackenzie Estuary, although it may cause local and short-term changes in the distribution of whales. Wage employment of hunters in the petroleum industry may change the pattern of hunting, but the workshop participants did not expect this to cause a substantial change in the size of the white whale harvest.

Hypotheses dealing with harvesting of resources are being examined in detail through the Mackenzie Environmental Monitoring Program (MEMP). This includes the possible effects of oil and gas development on white whale harvests, which was the subject of a subgroup meeting at the 1985 MEMP workshop.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 2-1

TITLE:	**Reactions of White Whales and Narwhals to Ship Traffic and Ice-breakers at the Admiralty Inlet Ice Edge.**
PRINCIPAL INVESTIGATOR:	S. Cosens
AFFILIATION:	Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE:	NOGAP
EXPECTED COMPLETION DATE:	1988
RELEVANT BEMP HYPOTHESIS NO.:	2

BRIEF PROJECT DESCRIPTION

This research project is an outgrowth of the studies conducted at the Admiralty Inlet ice edge in 1982-1984 (BEMP 1986). The study is designed to quantify vocal and behavioural responses of narwhals and white whales to ship traffic and icebreaking. Data are being collected on behaviour in the presence and absence of ship traffic, vocalizations and associated behaviour and responses to playback of ship noise.

BEMP IMPACT HYPOTHESIS NO. 2

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The study previously conducted at the Admiralty Inlet ice edge (BEMP 1986) provided information about sound transmission, vocalizations and behaviour of white whales in response to infrequent ship traffic. This present study will provide more detailed information about responses by whales to ships, and is focussing on behavioural differences between narwhal and white whales and the implications of these differences for predicting the impact of disturbance on behaviour and distribution. Although the study is being conducted in the eastern Arctic, the results will be of value in interpreting the observed reactions of white whales to ships in the nearshore Beaufort Sea (Hypothesis No. 2).

BEMP PROJECT OVERVIEW NO. 2-2

TITLE:	White Whale Surveys in the Beaufort Sea.
PRINCIPAL INVESTIGATOR:	T. Strong and P. Norton
AFFILIATION:	Department of Fisheries and Oceans; PN Enterprises
FUNDING SOURCE:	ESRF, NOGAP, DIAND
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	2

BRIEF PROJECT DESCRIPTION

This research is subdivided into three related projects:

1. visual surveys of white whales undertaken by PN Enterprises;

2. photographic surveys of white whales by DFO; and

3. surveys of selected transects by both methods.

The objective of the integrated program was to compare simultaneous counts of the number of whales in an area using a visual aerial survey technique and a photographic aerial survey technique. Comparison of the results will indicate a relative correction factor for the number of whales present but not detected. A rough calibration factor to be applied when comparing the results obtained by each method will also be derived. Data from the visual surveys have been analysed, but those from the photographic surveys are not yet available.

Systematic aerial whale surveys have been conducted annually in the Mackenzie Estuary and the offshore Beaufort since 1972 and 1980, respectively. All surveys employed the same visual survey technique. In some years, a second visual survey method was also employed to examine the number of surfaced whales missed by observers. This technique involved a comparison of counts of two

observers on the same side of the aircraft. A comparison of the two techniques, however, has not yet been conducted. The results of a similar study conducted in the eastern Arctic indicate that visual observers do miss some whales that can be detected in photographic surveys.

There are advantages and disadvantages to each technique. The visual survey technique affords a real-time observation period (whales' movement can be used as a sighting cue; a survey can be modified to maximize data collection). The visual technique is also cost-effective and less limited by weather than the photographic survey technique. The photographic technique, however, provides a permanent record of the observations, which allows for easy comparison of observer effectiveness and assessment of whale parameters that can not be accurately measured using the visual technique such as whale length and distances between whales.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this project will be useful in evaluating the validity of Hypothesis No. 2(c). This study will provide both population estimates and extent of icebreaker traffic, which can then be compared within and between years to determine if the abundance and distribution of white whales is altered by icebreaker traffic (Link 6). Such changes could, in turn, affect the white whale harvest levels through displacement of whales from hunting areas.

BEMP PROJECT OVERVIEW NO. 2-3

TITLE:	**Assessment of White Whale Responses to Boat Traffic through Detection of Vocalization.**
PRINCIPAL INVESTIGATOR:	G. Yaremchuk
AFFILIATION:	Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE:	NOGAP
EXPECTED COMPLETION DATE:	1988
RELEVANT BEMP HYPOTHESIS NO.:	2

BRIEF PROJECT DESCRIPTION

This study was initiated in 1985 with initial trials of the sonobuoy deployment in the inner Mackenzie estuary. The three objectives of this study were:

1. to assess sound transmission in the very shallow water of the inner estuary;

BEMP IMPACT HYPOTHESIS NO. 2

2. to determine whether changes in vocalization rate or type occur in the presence of disturbance from either industry or hunting boats; and

3. to determine, by triangulation, movements of whales in response to boat traffic.

Equipment problems in both 1985 and 1986 resulted in few data being collected. The data that were collected are not analysed to date. It is possible that this study will serve as the preliminary equipment testing for further research on this subject.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This research will provide information that is directly relevant to Links 5 and 6 of Hypothesis No. 2(c). Results of this study will assist in analysing whether ship traffic causes disturbance to white whales in the area, which could lead to changes in their abundance and distribution and ultimately the white whale harvest.

Participants in the 1985 BEMP workshop concluded that ship traffic at current levels did not reduce the number of animals that frequent the bays (Link 5), but that this may become a concern if traffic increases in the future. It was recommended that the above monitoring program as well as the Inuit liaison program be continued.

BEMP PROJECT OVERVIEW NO. 2-4

TITLE:	**Beaufort Sea White Whale Study.**
PRINCIPAL INVESTIGATOR:	Lois Harwood
AFFILIATION:	Fisheries Joint Management Committee
FUNDING SOURCE:	Fisheries Joint Management Committee
EXPECTED COMPLETION DATE:	ongoing
RELEVANT BEMP HYPOTHESIS NO.:	2

BRIEF PROJECT DESCRIPTION

This project was initiated by Tom Strong in 1981 for the Department of Fisheries and Oceans to obtain information on the population status, distribution, and stock identity of white whales hunted in the Mackenzie Estuary, and to collect catch/effort data for the Mackenzie domestic harvest. The objective of this program was to develop management recommendations for the Mackenzie white whale population.

BEMP IMPACT HYPOTHESIS NO. 2

Contractors obtained information through hunter interviews on catch/effort, total lengths, and gender of harvested whales. Biological information was also collected to determine age and reproductive status of the harvested whales. Stomachs examined in situ were found to contain little prey; no contents were collected.

In 1987, the project was continued under the Fisheries Joint Management Committee coordinated by Lois Harwood. The focus of this research is directed at the collection of harvest information and age determination as well as analysing stock separation of the Beaufort and Alaskan white whale populations. This analysis involves the collection of white whale livers for DNA fingerprinting.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

'Component A' of the monitoring program recommended in the 1983-84 and 1984-84 BEMP Final Reports include continuation of the annual monitoring of white whale harvest levels in the Mackenzie Estuary. This program is consistent with such recommendations, although it was initiated and is being continued for reasons other than the BEMP process. Information collected during the course of this annual monitoring program is not directly relevant to any of the Linkages in Hypothesis No. 2, but does provide important data on various population parameters of the Mackenzie white whale stock.

BEMP PROJECT OVERVIEW NO. 2-5

TITLE:	White Whale (*Delphinapterus leucas*) Population Management in Northern Canada: A review of Stock Discreteness and Size of Sub-arctic Populations.
PRINCIPAL INVESTIGATOR:	P.R. Richard
AFFILIATION:	DFO
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. December 5-9, 1987, Miami, Florida.
EXPECTED COMPLETION DATE:	1990
RELEVANT BEMP HYPOTHESIS NO.:	2

BRIEF PROJECT DESCRIPTION

The following is an abstract that appears in the Seventh Biennial Conference on the Biology of Marine Mammals Abstracts, December 1987.

BEMP IMPACT HYPOTHESIS NO. 2

In 1980, the IWC Sub-Committee on Small Cetaceans proposed a model suggesting that white whale populations could be separated between year-round resident populations and summering populations, which share common wintering grounds. The western Hudson Bay population was given as an example of the former and the eastern Hudson Bay and Cumberland Sound populations as examples of the latter.

Results from extensive surveys flown between 1981 and 1986 by Fisheries and Oceans and others provide a different picture of white whale seasonal distribution. For example, large numbers of white whales have been counted in both southern and northern Hudson Bay. This suggests that, in summer, white whales have a near continuous distribution in Hudson Bay. In addition, the western Hudson Bay summer concentration is not a year-round resident population. It shares the Hudson Strait wintering grounds with the eastern Hudson Bay population and probably with the Cumberland Sound population. The Cumberland Sound population appears to move into Frobisher Bay during the summer.

These results indicate that white whales are more widely distributed in summer than was previously thought. Stock delineation by summer concentrations may be an over-simplification that could be counterproductive in attempts to manage native harvests. New population size estimates are also presented for S.E. Baffin Island, N. Hudson Bay and W. Hudson Bay summer concentrations.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Although this study is not directly relevant to BEMP, it does provide some important information on the population structure of white whales in Canadian waters. Information on abundance, distribution, and yearly movements from this study can be useful in assessing similar information obtained from the Beaufort Sea that is directly relevant to Hypothesis No. 2.

BEMP IMPACT HYPOTHESIS NO. 2

BEMP PROJECT OVERVIEW NO. 2-6

TITLE:	White Whale (*Delphinapterus leucas*) Movement Analysis Study
PRINCIPAL INVESTIGATOR:	T. Strong
AFFILIATION:	Department of Fisheries and Oceans
FUNDING SOURCE:	DFO, FJMC, Alaska Dept. Fish and Game
EXPECTED COMPLETION DATE:	1991
RELEVANT BEMP HYPOTHESIS NO.:	2

BRIEF PROJECT DESCRIPTION

The major objective of this 4-year study is to monitor daily movements, dive and surface times, and migration routes of tagged white whales using radio and satellite telemetry. It was hypothesized that areas of whale concentration during migration are site specific and that there is no population interchange.

Four whales are to be tagged and monitored in order to study their movements, migration, and population interchange. Two whales were radio-tagged in 1988. One transmitted for one week before the signal was lost, the other is currently being monitored visually and by telemetry. The existing tag is being redesigned and strengthened. A minimum of three more whales are to be tagged in 1989. It is expected that this research will be completed by 1991, with updates prepared annually.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

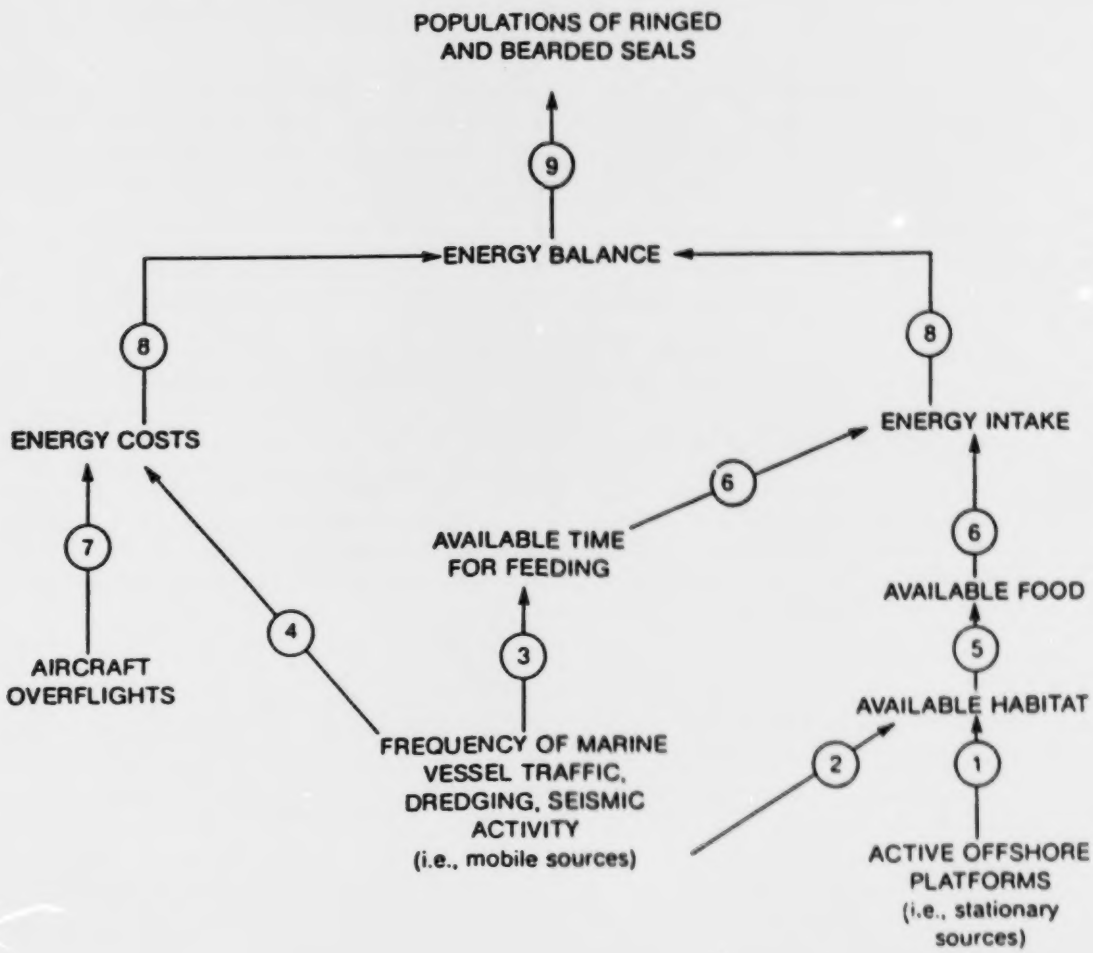
Hypothesis No. 2c states that "open water ship traffic in the Mackenzie Estuary will alter white whale distribution and lead to changes in harvest levels". Results from this study will provide important distributional information required to assess this component of the hypothesis. This is the first research of this type to examine the migration patterns of white whales. When available, the results will provide new and vital information with which to evaluate Hypothesis 2c.

HYPOTHESIS NO. 3

Marine vessel traffic, seismic activities, dredging operations, aircraft overflights and active offshore platforms/islands will reduce the size of populations of ringed and bearded seals.

FIGURE 3-1

THE EFFECTS OF VARIOUS OFFSHORE ACTIVITIES AND FACILITIES ON POPULATIONS OF RINGED AND BEARDED SEALS IN THE BEAUFORT SEA



BEMP IMPACT HYPOTHESIS NO. 3

LINKAGES

1. Each active offshore platform will result in the exclusion of ringed and bearded seals from some habitat.

2. Marine traffic (ships, dredges, seismic vessels) will exclude ringed and bearded seals from available habitat.

3. Each passage of a ship or other marine vessel will reduce the feeding time available to ringed and bearded seals.

4. Each passage of a vessel will increase the energy expenditure of seals because of avoidance behaviour.

5. The available aquatic habitat can influence the level of available food.

6. The amount and quality of available food and the time available for feeding determine energy intake.

7. Noise from aircraft will disturb hauled-out seals and lead to increased energy costs.

8. Energy intake and costs determine energy balance.

9. The energy balance of a seal determines its survival and its ability to reproduce. The energy balance of the individuals in a population influences the reproductive capacity and health of the population.

BEMP IMPACT HYPOTHESIS NO. 3

STATUS OF KNOWLEDGE REGARDING BEMP IMPACT HYPOTHESIS NO. 3

This hypothesis and its linkages were expected to remain valid, but it was concluded during the 1985 workshop that the cumulative effects of all links would probably be inconsequential or too hard to detect (due to natural variability in population levels) at the present level of industrial activity in the Beaufort region. For example, studies conducted by DFO (Central and Arctic Region, formerly Western Region) since 1981 have shown no correlation between densities of hauled-out seals and proximity to industrial activities. Habitat exclusion resulting from the physical presence of offshore structures and marine vessel traffic were expected to be insignificant at both individual and population levels, while the energetic costs associated with avoidance and diving responses to aircraft overflights would also be inconsequential from a regional perspective. No specific research or monitoring were recommended.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 3-1

TITLE:	**Changes in the Population Dynamics of Ringed Seals in the Amundsen Gulf**
PRINCIPAL INVESTIGATOR:	T.G. Smith
AFFILIATION:	Fisheries and Oceans Canada, Arctic Biological Station
FUNDING SOURCES:	DFO, Polar Continental Shelf Project
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	3, 4, 6, and 9

BRIEF PROJECT DESCRIPTION

This study involves the compilation and integration of extensive amounts of data collected by the Arctic Biological Station on the Amundsen Gulf ringed seal population during the period from 1971 to 1983. This long-term program has included investigation of various aspects of ringed seal population structure, recruitment, annual movements and physiological condition. Samples were collected in several areas within Amundsen Gulf including Minto Inlet, Prince Albert Sound, Prince of Wales Strait and Cape Parry, as well as other areas in the southeast Beaufort Sea.

The results indicate that Prince Albert Sound supports the highest density of ringed seals (2.84/sq km) and that the population extends as far as Point Barrow, Alaska and Injun, Siberia. This high density of seals in Prince Albert Sound is due to the presence of stable landfast ice, which is used as their breeding habitat. A drastic reduction in recruitment of seals was noted in 1974

and 1975, but the precise cause of this decline has not been identified.

Many aspects and components of this research have been presented elsewhere. The overall integration and interpretation of information resulting from this study, including resolution of seasonal and year-to-year changes, required the use of computerized techniques of data analysis and simulation. Integrated ecosystem research with radio and satellite telemetry was suggested to more effectively study the regulation of marine mammal populations. Topics covered include: ringed seal distribution abundance, breeding habitat, reproduction, growth and body condition, feeding ecology, and demographic parameters. The results of this research are published in the 1987 Canadian Bulletin of Fisheries and Aquatic Sciences, No. 216.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study provides information relevant to Link 9 of Hypothesis 3, through examination of effects of energy balance on ringed seal growth, survival and reproduction.

Smith's study is also relevant to Hypothesis 4 and 6, which relate to the effects of icebreaking in Amundsen Gulf on seal (and polar bear) populations. Examination of seasonal and annual variability in seal distributions and ice conditions will be particularly useful for analysis of Links 2 and 4 (Hypothesis 4) and Links 10 and 11 (Hypothesis 6).

There is concern that icebreaker traffic through Amundsen Gulf will affect ringed seal and polar bear populations, through alteration of ice type, coverage and location. Participants in the second BEMP workshop (INAC and Environment Canada 1985) concluded that, although such ship-induced destabilization of the Amundsen Gulf ice cover was not very probable, this area of concern deserved further consideration because of the potential serious nature of resultant impacts on seal and bear populations. Analysis of existing data was recommended to examine the effects of yearly changes in ice conditions on the distribution and abundance of marine mammal populations, and the data collected by Smith was identified as an important source of information for such an analysis. Examination of the 12 years of data will allow analysis of the relationship between variations in ice cover (most notably the extreme ice years of 1971, 1978 and 1981) and changes in ringed seal population parameters.

BEMP IMPACT HYPOTHESIS NO. 3

BEMP PROJECT OVERVIEW NO. 3-2

TITLE:	**Environmental and Ecological Factors Influencing Ringed Seal Distribution in the Southeast Beaufort during Late Summer/Fall**
PRINCIPAL INVESTIGATOR:	L. Harwood
AFFILIATION:	Department of Zoology, University of Alberta
FUNDING SOURCES:	Fisheries and Oceans Canada, Indian and Northern Affairs Canada, Minerals Management Services, Boreal Institute of Northern Studies, University of Alberta
EXPECTED COMPLETION DATE:	1989
RELEVANT BEMP HYPOTHESIS NO.:	3 and 9

BRIEF PROJECT DESCRIPTION

This project has involved examination of the relative abundance and distribution of ringed seals in the Beaufort Sea during the open-water period for the years 1980-1986. Trends in seal distribution will be examined through comparison with oceanographic features depicted in satellite imagery or delineated through in situ sampling. In addition, a population estimate will be attempted as part of this study.

During the open-water period, ringed seals occur in large (10's of 1000's), dense feeding aggregations, and these appear to persist through to freeze-up. The locations of groups varies among years, and this is believed to be related to variation in the distribution of seal prey items (e.g., zooplankton, Arctic cod).

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Seal distribution data collected from 1980-1986 will be useful in evaluating Links 1 and 2 of Hypothesis 3, which state that active offshore platforms and marine traffic will exclude ringed (and bearded) seals from some available habitat. However, since the project was not designed to determine a cause-effect relationships, quantification of subtle exclusions is not possible. The surveys do provide an extensive time series describing seal distribution in areas in the vicinity of and distant from industry activities. This information along with the oceanographic data, will be used to assess any evidence for large-scale exclusions of seals. Preliminary analyses to date suggest there have not been such effects, at least not to an extent detectable with methods employed in this investigation.

The study will also provide information relevant to Links 5 and 6 of Hypothesis 3, through an examination of the importance of fall feeding in the annual nutrition of ringed seals. If ringed seals are excluded from available

and important feeding areas (e.g., if Links 1 and 2 are in fact valid and consequential), then information from this study could be used to evaluate the possible implications of such an exclusion. The seriousness of any exclusion would depend on its location and timing.

The investigation also involves evaluation of the validity of using aerial surveys to census ringed seals during the open-water period, the advantages and disadvantages of employing this method, and presentation of correction factors. Consequently, the methodological component of this study is also relevant to Links 1 and 2 of Hypothesis 3, which rely on monitoring the distribution and relative abundance of seals.

BEMP PROJECT OVERVIEW NO. 3-3

TITLE:	**Density and Distribution of Ringed Seals in Barrow Strait during Late Winter and Spring**
PRINCIPAL INVESTIGATOR:	M.O. Hammill
AFFILIATION:	MacDonald College, McGill University, and Arctic Biological Station, Fisheries and Oceans Canada
FUNDING SOURCES:	DFO (NOGAP) and petroleum industry
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	3, 4 and 6

BRIEF PROJECT DESCRIPTION

This study was designed to quantify the effects of certain habitat features on the density and distribution of ringed seals in fast ice. To achieve this objective, it was necessary to develop a method that provided a reliable estimate of seal abundance.

Labrador retrievers, trained to located ringed seal structures (lairs), searched 12 different 4 km^2 plots between March and June 1984. In each plot, all seal structures located by the dogs were marked. By treating the marked structures as removals (Zippin, Biometrics 12:163-189, 1956) the population of structures in each plot was estimated.

Nine of the areas searched in 1984 were also searched in 1985 and 1986, and population estimates were obtained where the probability of detection of seal structures remained constant. Seal hole densities from all areas searched during the three years were also compared.

The removal method proved to be satisfactory in estimating the number of seal holes per unit area. Application of the model permits the quantification of year-to-year changes in density and distribution of ringed seals within their breeding habitat.

BEMP IMPACT HYPOTHESIS NO. 3

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The methodological component of this study is applicable to Links 1 and 2 of Hypothesis 3, which involve estimation of seal distribution and abundance. The analysis of ringed seal density and distribution during breeding is directly relevant to evaluation of Link 2 of Hypothesis 4 and Link 11 of Hypothesis 6.

BEMP PROJECT OVERVIEW NO. 3-4

TITLE:	Status of the Ringed Seal Population.
PRINCIPAL INVESTIGATOR:	M. Kingsley and T. Byers
AFFILIATION:	Department of Fisheries and Oceans, Freshwater Institute.
FUNDING SOURCE:	Fisheries Joint Management Committee
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	3, 4 and 6

BRIEF PROJECT DESCRIPTION

A sample of 75 ringed seals (36 females and 39 males) were collected to determine the current status and physiological condition of the Thesiger Bay population. The seals were collected from July 12 - Aug 16, 1987.

The population structure was heavily skewed toward older seals, with very few 1- to 3-year-olds found and only 2 ringed seal pups. High organochlorine levels were found in the blubber, but these were not sufficiently high to influence reproduction. No other pathological conditions were noted in the samples.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study will provide information that is directly relevant to Hypothesis 3 as well as Hypothesis 4, which states that increased frequency of icebreaker traffic through the landfast ice and through Amundsen Gulf will reduce ringed seal pup production levels and have subsequent effects on population levels. The results of the study will provide baseline data on the population status for comparison with similar monitoring studies to determine the effects of icebreaker traffic on the population and abundance of marine mammal populations.

BEMP IMPACT HYPOTHESIS NO. 3

BEMP PROJECT OVERVIEW NO. 3-5

TITLE:	**Long-term Studies of Ringed Seal (*Phoca hispada*) Distribution in Alaska.**
PRINCIPAL INVESTIGATOR:	K.J. Frost, J.J. Burns, J.R. Gilbert, and L.F. Lowry
AFFILIATION:	Alaska Department of Fish and Game, Living Resources, University of Maine
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. Dec. 5-9, 1987, Miami, Florida.
RELEVANT BEMP HYPOTHESIS NO.:	3, 4 and 6

BRIEF PROJECT DESCRIPTION

Aerial surveys of ringed seals, *Phoca hispada*, have been conducted intermittently in Alaska since 1970. In 1985, a 3-year study was initiated to evaluate historical data and to determine the feasibility of long-term monitoring of ringed seal distribution and abundance through aerial surveys. The specific objectives were to: (1) develop a survey protocol that could be duplicated in future years; (2) identify trends in abundance; and (3) determine the effects of industrial activity on the distribution and abundance of ringed seals.

The 1985-1987 surveys provided density estimates with 95% confidence limits equal to the mean +/- 10-16%. Density estimates from surveys flown at 300 ft (91.5 m) were approximately 1.3 times higher than estimates from 500 ft (152.5 m). This indicates that for long-term studies the flying altitude must be consistent among surveys or the data must be calibrated. Replicate surveys of the same area, flown 3-4 days apart, within the prescribed weather window and with similar ice conditions resulted in statistically similar density estimates. Surveys of those same areas after the ice began to break up resulted in significantly different densities. This was attributed primarily to the fact that the seals aggregated at cracks, particularly within 2 nm of the fast ice edge. Density increased only 9% within 6 nm of land, suggesting that the nearshore zone can be used in year-to-year comparisons when surveys are flown after ice break-up. It was suggested that a coordinated ground study of seal haul-out behaviour be implemented to compliment information from aerial studies and provide the basis for long-term monitoring of changes in ringed seal distribution and abundance.

BEMP IMPACT HYPOTHESIS NO. 3

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study provides information that is indirectly relevant to Hypothesis 3, 4 and 6. Although the study was conducted in Alaska, the information can be useful in assessing similar information collected in the Canadian Beaufort.

The seal distribution data will be useful in evaluating Links 1 and 2 of Hypothesis 3. The surveys have provided an extensive time series of data that describe seal distribution in areas in the vicinity of and distant from industry activities, which can be used to assess any evidence for large-scale exclusions of seals. This investigation is also considered important because it will provide evaluation of the validity of using aerial surveys to census ringed seals, and the merits and shortcomings of this method.

BEMP PROJECT OVERVIEW NO. 3-6

TITLE:	Function of the Ringed Seal Subnivean Lair.
PRINCIPAL INVESTIGATOR:	M.O. Hammill and T.G. Smith
AFFILIATION:	Renewable Resources: Wildlife, Macdonald College
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. Dec. 5-9, 1987, Miami, Florida.
RELEVANT BEMP HYPOTHESIS NO:	3 and 4

BRIEF PROJECT DESCRIPTION

The following is an abstract that appears in the Seventh Biennial Conference on the Biology of Marine Mammals Abstracts, December 1987.

In winter ringed seals (*Phoca hispada*) maintain breathing holes in the fast ice and dig lairs beneath the snow for resting or for use in the spring as pupping sites. These provide protection from cold temperature and predators. The proportion of structures maintained by seals as subnivean lairs is tied to the availability of adequate snowcover. Recently predator avoidance has been suggested as the primary stimulus for the evolution of the subnivean lair. Therefore, we predict increased predation of ringed seals in areas where there is little snow cover and reduced predation with increased snowcover.

Snow thickness and predation were examined at thirty-three study plots in Barrow Strait between March and May, 1984-1986. Polar bears were the most important predator. Predation occurred primarily at birth lairs which formed 20 to 40% of the structures located. No relationship was identified between predation and snow depth in the 1984 and 1985 possibly due to the small sample

sizes from each of these years (N=9). In 1986, predation attempts were correlated with snow depth as predicted (r= -0.6215 p=0.02 N=14) and with date (r=0.6819 p=0.01 N=14). The incidence of kills was correlated to predation attempts (r=0.8075 p=0.0005) and date (r=0.6653 p=0.01).

It was concluded that construction of the subnivean lair has been in response to predation pressure, especially predation on pups. The thick dome of snow interferes with the predator's ability to detect a seal's location and acts as a barrier, inhibiting the predator's entry into the lair. They also provide an important thermal shelter for pups, but this is only required after their immersion in water in response to disturbance from predators.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study provides information on the function of the ringed seal subnivean lair, which is indirectly relevant to Hypothesis 3 and 4. Offshore activities and ice-breaker traffic could influence ice and snow conditions and, thereby, cause a change in the effectiveness of subnivean lairs for protection of seals from predators. Such changes could have significant influence on pup production and population abundance and distribution.

BEMP PROJECT OVERVIEW NO. 3-7

TITLE:	**Patterns of Aggregation in Ringed Seals, Bearded Seals and Bowhead Whales in the Beaufort Sea during Late Summer.**
PRINCIPAL INVESTIGATORS:	L.A. Harwood and I. Stirling
AFFILIATION:	University of Alberta, Canadian Wildlife Service.
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. December 5-9, 1987, Miami, Florida.
RELEVANT BEMP HYPOTHESIS NO:	1, 3 and 4.

BRIEF PROJECT DESCRIPTION

The following is an abstract that appears in the Seventh Biennial Conference on the Biology of Marine Mammals Abstracts, December 1987.

Systematic strip-transect aerial surveys to count marine mammals were flown twice annually over the SE Beaufort Sea during August-September of 1982, and 1984-1986. The region was subdivided into 255 grid cells (353 km each) between 141 and 127 W longitude, and from the 2m isobath seaward to 25 km beyond the shelf break. Size of the overall study area was 90,000 km, and survey coverage

was 2-10%. Each marine mammal sighting was assigned to a grid cell, and mean densities calculated for each year using corrections for observation conditions, and using only data collected by the one observer present on all flights in all years. Mean cell densities were used to produce contour maps depicting annual distribution patterns for each species.

Densities for ringed seals, bearded seals, and bowhead whales are examined at the group, single grid cell, and multiple grid cell scales using Taylor's Law of the Mean in order to compare their patterns of aggregation. Patterns in all species in all years were clumped, but were different among years and between species.

In three of the four years, dense aggregations of ringed seals were observed in both nearshore and offshore (50-80 km) waters, but the number of aggregations and their locations varied. Observed seal behaviour, and the presence and behaviour of seabirds, feeding bowhead whales, and bearded seals within or near the ringed seal aggregations suggest feeding is a major activity therein. In 1986, three areas of seal aggregation were found, and mean cell densities were 1.67-1.75 ringed seals/km surveyed area, and 54% of the on-transect sightings. Ringed seal density in remaining areas considered overall was 0.14/km surveyed.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is of relevance to Hypothesis 1, 3 and 4, which link ship traffic and offshore activities to reductions in population sizes of ringed seals, bearded seals, and bowhead whales in the Beaufort Sea. Distribution and abundance information provided from this study are useful for assessing the numbers of marine mammals that might be affected by such activities.

BEMP IMPACT HYPOTHESIS NO. 3

BEMP PROJECT OVERVIEW NO. 3-8

TITLE:	**Predation on Ringed Seals in the Western Beaufort Sea.**
PRINCIPAL INVESTIGATORS:	B.P. Kelly, S.C. Amstrup, C. Gardner, and L.T. Quakenbush
AFFILIATION:	Institute of Marine Science, Univ. of Alaska, and U.S. Fish and Wildlife Service
SOURCE:	Seventh Biennial Conference on the Biology of Marine Mammals. Abstracts. December 5-9, 1987, Miami, Florida.
RELEVANT BEMP HYPOTHESIS NO:	3, 4 and 6

BRIEF PROJECT DESCRIPTION

The following is an abstract that appears in the Seventh Biennial Conference on the Biology of Marine Mammals Abstracts, December 1987.

Polar bears (*Ursus maritimus*) and arctic foxes (*Alopex lagopus*) are the principal predators of ringed seals (*Phoca hispada*) and may exert considerable influence on seal populations. Arctic foxes prey only on ringed seal pups in subnivean birth lairs, whereas the bears also prey on older seals in and out of the lairs. Rates of predation by foxes can be measured by random surveys of seal lairs, using trained dogs, but predation rates by bears appear to be poorly estimated by this method.

Trained dogs were used to locate 203 lairs, including 20 pupping lairs in the western Beaufort Sea in 1982 to 1987. Foxes entered 14.4% of the lairs and killed pups in 4 (20%) of the birth lairs. Those rates agree well with data from other parts of the Arctic and are believed to be accurate estimates of the actual rates in the Alaskan Beaufort Sea.

Polar bears entered only 3 (1.5%) of 196 lairs located during random searches in 1982-1987. No kill was made at that site. While tracking bears from low-flying aircraft near the areas surveyed with the dogs, indications of much higher rates of kills at lairs were observed.

Quantification of the take of ringed seals by radio-collared bears in relation to the densities of seal lairs and breathing holes was initiated, using trained dogs to locate those structures within 2 km of tracks paralleling the paths of the bears. In April 1987, along 51.5 km of polar bear tracks in the western Beaufort Sea, polar bears attempted without success to capture seals at 8/20 (40%) breathing holes, 3/9 (33%) resting lairs, and 2/2 (100%) pupping lairs located by the dogs. Three adult females averaged one attempt every 6.84 km.

BEMP IMPACT HYPOTHESIS NO. 3

An additional 145 seal structures were located during random surveys with the dogs and while tracking bears from low-flying aircraft in April and May 1987. In all, 29 breathing holes, 16 resting lairs, and 12 birthing lairs in which bears attempted to capture seals were examined. Seals were killed at 10.3% of those breathing holes, 6.2% of the resting lairs, and 75.0% of the birth lairs.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

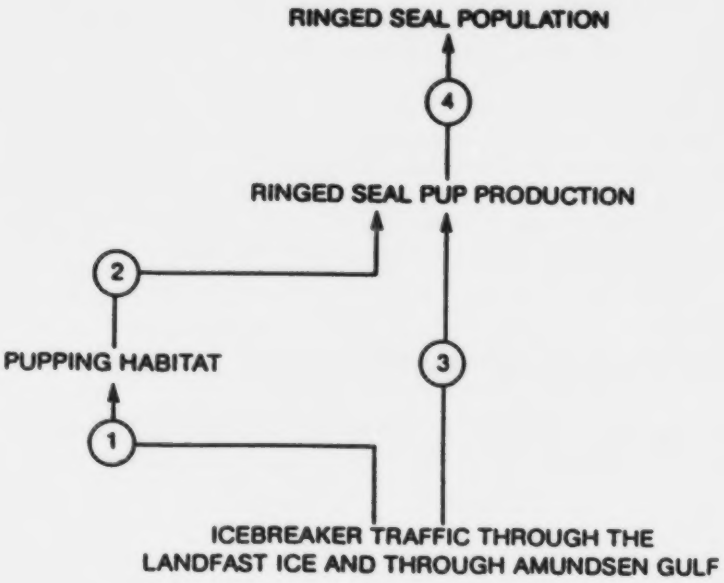
This study is indirectly relevant to Hypothesis 3, 4 and 6. There is concern that icebreaker traffic through the Beaufort Sea will affect ringed seal and polar bear populations through exclusion from or decrease in available habitat. In addition to providing basic information on the distribution and abundance of these populations, this study will also provide information on the relationship between ringed seals and polar bears, which could be valuable in assessing the effects of icebreaker traffic and offshore activities on these populations.

HYPOTHESIS NO. 4

Increased frequency of icebreaker traffic through the landfast ice and through Amundsen Gulf will reduce ringed seal pup production and population levels.

FIGURE 4-1

POTENTIAL EFFECTS OF INCREASED FREQUENCY OF ICEBREAKER TRAFFIC THROUGH THE LANDFAST ICE AND THROUGH AMUNDSEN GULF ON RINGED SEAL PUP PRODUCTION AND POPULATION LEVELS



LINKAGES

1. Icebreaking vessels operating in the landfast ice and through Amundsen Gulf will decrease the amount of pupping habitat available for ringed seals.

2. Adequate pupping habitat is necessary for the production of ringed seal pups.

3. Icebreaker traffic in late March, April and May will kill ringed seal pups.

4. Reduced ringed seal pup production will result in lower population levels.

BEMP IMPACT HYPOTHESIS NO. 4

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 4

After reviewing this hypothesis and its linkages, the 1985 workshop participants concluded that it remained valid in the form presented in the 1983-84 BEMP report. However, a fourth link was added to indicate that reduced ringed seal pup production could result in lower population levels, and the hypothesis was re-worded to reflect this change. It was concluded that the areas of ringed seal breeding habitat that may be lost due to icebreaker traffic would be small in relation to available habitat in the region. Direct loss of ringed seal pups in icebreaking corridors would occur, but were expected to be a small proportion of total pup production.

During the link-by-link review of this hypothesis, 1985 workshop participants discussed research that would substantially increase understanding of factors affecting ringed seal pup production in Amundsen Gulf, and the potential impact on pupping habitat of ice cover destabilization associated with icebreaking. It was generally agreed that much of this research would not be possible until some icebreaker traffic occurs in the Gulf. On the other hand, the group recommended continued collection of satellite imagery to provide the basis for future analysis of the relationships between ice conditions and production and survival of ringed seals, and to address the question of destabilization of the ice cover due to icebreaker traffic.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

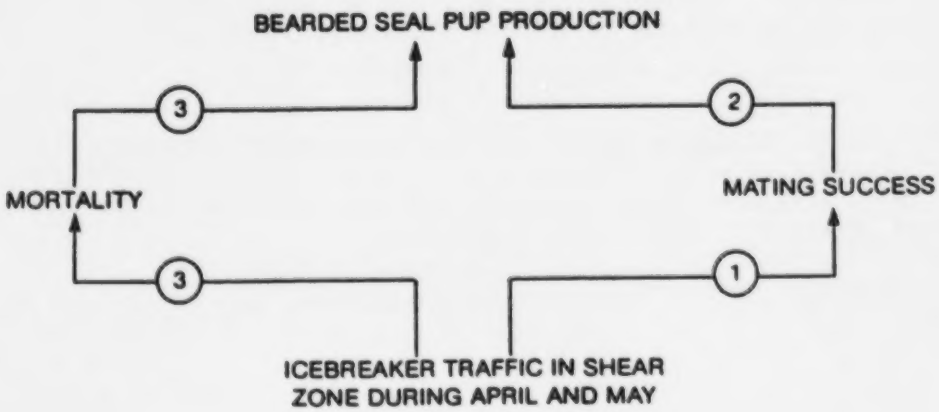
There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 5

Icebreaker traffic in the transition (shear) zone will reduce bearded seal pup production.

FIGURE 5-1

POTENTIAL EFFECTS OF ICEBREAKER TRAFFIC IN THE TRANSITION ZONE ON BEARDED SEAL PUP PRODUCTION



LINKAGES

1. Icebreaker traffic in the shear zone during April and May will interfere with vocalizations of male bearded seals, and this will result in reduced mating success.

2. Successful mating is necessary for production of bearded seal pups.

3. Icebreaker traffic in the shear zone during April and May will result in mortality of bearded seal pups.

BEMP IMPACT HYPOTHESIS NO. 5

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 5

During the 1985 workshop, the participants concluded that Hypothesis No. 5 remained valid. The group concluded that a research program could be designed to determine the direct effects of icebreaker traffic on seal vocalizations, but since these studies are unlikely to provide information on how decreased vocalization rates may affect mating behaviour or success, they were considered a low priority in the context of the hypothesis.

Icebreaker traffic in the transition zone will result in mortality of some bearded seal pups, but losses were expected to be extremely small given the present development scenario. Because it would be difficult to detect changes in pup production following the anticipated small losses, no research or monitoring was recommended to address this aspect of Hypothesis No. 5.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

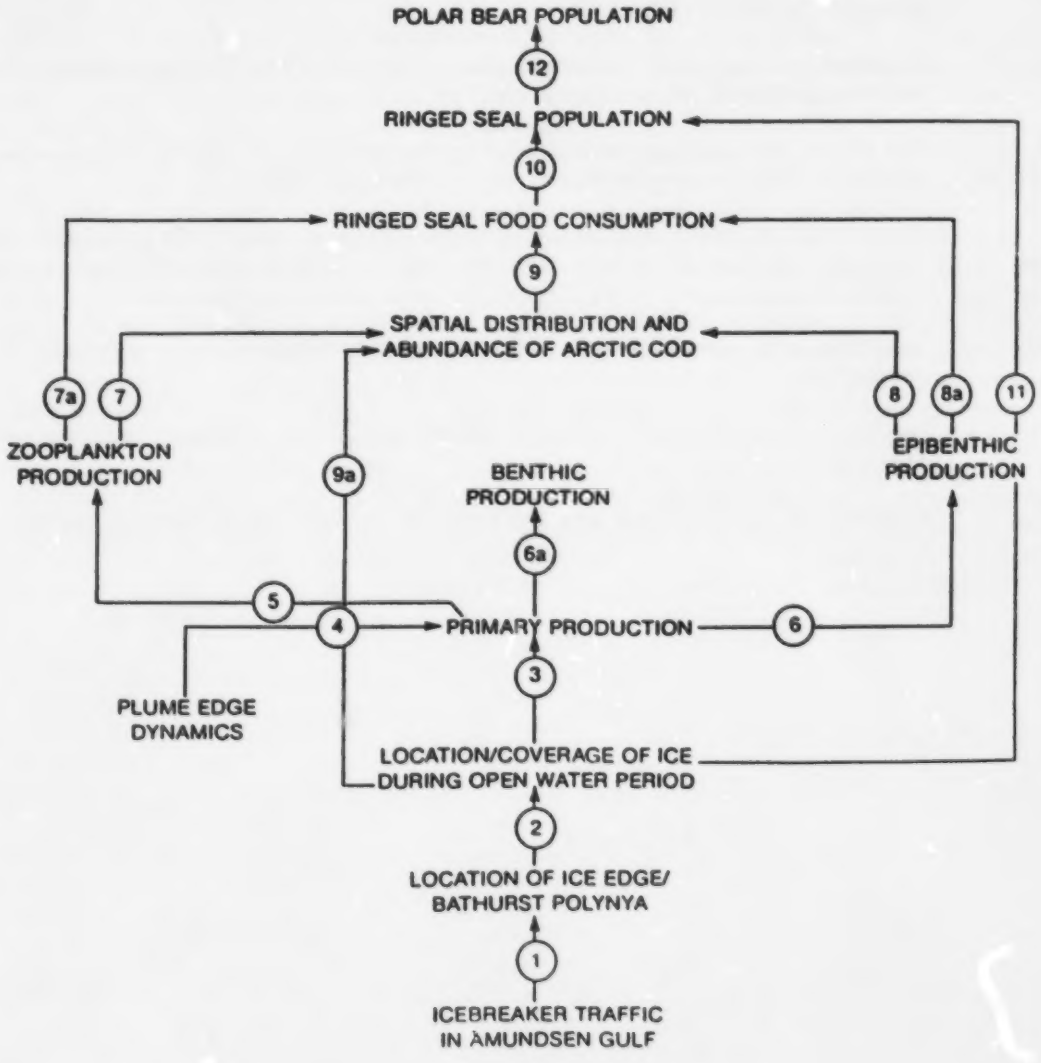
There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 6

Icebreaker traffic in Amundsen Gulf will affect the ringed seal a polar bear populations.

FIGURE 6-1

POTENTIAL EFFECTS OF ICEBREAKER TRAFFIC IN AMUNDSEN GULF ON THE RINGED SEAL AND POLAR BEAR POPULATIONS



BEMP IMPACT HYPOTHESIS NO. 6

LINKAGES

1.	Icebreaker traffic in Amundsen Gulf will move the stable ice edge to the east (and alter the Bathurst polynya) in winter and spring.
2.	Movement of the stable ice edge may in turn change the total amount of open water in the region.
3.	The coverage thickness and location of ice determine the level of primary productivity.
4.	Primary production is enhanced (perhaps in patches) near the Mackenzie River plume edge.
5, 6 and 6a	The level of primary productivity determines the level of secondary productivity in zooplankton, epibenthos and benthos.
7, 8 and 9a	Distribution and production of zooplankton and epibenths and the location of ice determine the production and distribution of Arctic cod..
10.	Quality and quantity of food determine ringed seal survival and mortality.
11.	Location and type of ice are important in determining ringed seal distribution.
12.	Numbers of polar bears are determined by numbers of ringed seals.

BEMP IMPACT HYPOTHESIS NO. 6

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 6

The complexity and testability of this hypothesis was a subject of much discussion during the 1985 workshop because it encompasses all the trophic levels in the marine ecosystem of Amundsen Gulf, and involves processes and biological resources that are characterized by a high degree of natural variability. Nevertheless, the hypothesis itself was expected to remain valid. Several research projects by DFO will provide information relevant to one or more of its linkages. Studies of ringed seals (Arctic Biological Station) and polar bears (Canadian Wildlife Service) have provided data that will be useful in evaluation of upper links in the hypothesis.

Many of the uncertainties associated with Hypothesis No. 6 relate to the limited information on Arctic cod and its trophic relationships in the region. However, field studies initiated by DFO (Freshwater Institute) should provide some additional information on the abundance and distribution of this species when results of these investigations become available.

Other than continuation of ongoing research programs related to this hypothesis, no research or monitoring program directed explicitly at any of its linkages were recommended in 1985. However, the workshop subgroup identified two general concerns regarding the availability of fundamental data on ice cover in the Beaufort Sea and Amundsen Gulf. Firstly, the present limited communication between life science specialists and ice scientists was believed to be hampering research programs. It was recommended that increased cross-disciplinary contact between these groups be encouraged. The second concern was that no effort is presently being directed at assuring the continued availability of low-cost ice data such as daily, full resolution NOAA satellite imagery. The group concluded that attempts should be made to ensure that sea ice data collection and analysis are continued to the extent required for the optimal interpretation of the results of biological studies. Summary catalogs of available imagery should be prepared for future access by researchers in the Beaufort region.

BEMP IMPACT HYPOTHESIS NO. 6

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 6-1

TITLE:	Arctic Cod Distribution, Abundance and Vulnerability to Perturbation
PRINCIPAL INVESTIGATOR:	R. Crawford
AFFILIATION:	Fisheries and Oceans Canada Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
RELEVANT BEMP HYPOTHESIS NO.:	6

BRIEF PROJECT DESCRIPTION

The overall objectives of this study are to: (1) determine the distribution and abundance of Arctic cod in various habitats and during various phases of its life cycle; and (2) delimit the spawning season of Arctic cod and identify major spawning locations. This study was initiated in 1984, with sampling effort focussed in Resolute Bay. The 1986 sampling program continued to focus on Resolute Bay, but also involved hydroacoustic surveys at sites outside this area to obtain information on the abundance and distribution of Arctic cod and other fish species in the Beaufort Sea.

During the ice season, hydroacoustic surveys were conducted at sites in Resolute, Allen and Radstock bays, Barlow, Gascoyne and Griffin inlets, Resolute Passage, Wellington Channel, McDougall Sound, Queens Channel and the mouth of Admiralty Inlet. Results of these surveys indicated that fish were more abundant than in previous years and appeared to be most abundant near the landfast ice edge. During the open-water season, sampling was limited to within Resolute Bay. Arctic cod were collected using bottom trawls and gill nets and were observed using underwater video equipment. All fish collected were aged and their stomach contents and sex determined.

In spring 1987, preliminary under-ice acoustic surveys were conducted in the nearshore zone off the Tuktoyaktuk Peninsula for Arctic cod. During the open-water season, a hydroacoustic survey was also completed in conjunction with trawling for ground truthing. Results of this field work are not yet available, however data analysis is on-going. Further field work is planned for 1988/89.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Research on Arctic cod and the role of this species in the diets of its predators is relevant to any impact hypothesis that involves either direct or indirect linkages (through trophic relationships) between industrial development activities and key species of marine mammals or seabirds. This study is

particularly relevant to Hypothesis No. 6 "Icebreaker traffic in Amundsen Gulf will affect the ringed seal and polar bear populations", because information may be obtained on spatial and temporal patterns in the abundance and distribution of Arctic cod, which in turn affect ringed seal food consumption (Link 9), seal population dynamics and therefore polar bear populations.

BEMP PROJECT OVERVIEW NO. 6-2

TITLE:	**Mackenzie Shelf Fisheries Habitat Research**
PRINCIPAL INVESTIGATORS:	M. Lawrence
AFFILIATION:	Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
EXPECTED COMPLETION DATE:	1991
RELEVANT BEMP HYPOTHESIS NO.:	6, 19, and of general interest

BRIEF PROJECT DESCRIPTION

The Mackenzie shelf fisheries habitat research was initiated in 1984. The planning for this study was discussed in 1985 BEMP Project Overview No. 30. During 1985, two other projects (1985 Project Overview No. 17, Fish feeding ecology; and Project Overview No. 23, The biological importance of Tuktoyaktuk Harbour to fish) became part of the overall fish habitat investigation.

The major objectives of this investigation are:

1. to identify, in both spatial and temporal terms, the areas of the Mackenzie shelf from Demarcation Pt. to Cape Bathurst that are of significance to estuarine and marine fish;

2. to characterize areas of important or critical marine habitats in terms of their physical-chemical environment, biotic community structure or production; and

3. to describe the feeding habits of selected pelagic and demersal fish species of the Mackenzie Shelf in relation to habitat and season (open water vs. ice cover).

In 1986, biological and oceanographic sampling was conducted at 71 locations on the MacKenzie Shelf over the period from May to September. Gillnets were used to sample fish under the ice, while bottom trawls were employed during the open-water period. Oceanographic sampling was conducted from Herschel Island to Cape Bathurst from July to September. Horizontal and oblique tows with 500 μ mesh gear were used to sample larval fish, zooplankton and neuston, while vertical tows with a 83 μ mesh net were conducted to determine the availability and abundance of larval fish food. Distribution and abundance data for major

species are being compiled and mapped in relation to oceanographic parameters (depth, temperature, salinity, nutrients and chlorophyll). In addition, NOAA-6 satellite imagery is being assessed to determine the relationship of sea surface colour and thermal attributes to biomass of selected species.

In 1987, mid-water trawls were also made at various locations on the Mackenzie estuary and shelf. Results of sampling indicated that there was a significant abundance of juvenile Arctic cod in these areas. During this field year, increased emphasis was also placed on examining the biomass and distribution of ice algae as it relates to several abiotic factors such as salinity, ice clarity and snow depth. Primary productivity studies initiated in 1986 were continued during the latter half of July and August. Further investigation of ice algae was carried out during the March 1988 field program, which was expanded to include snow-ice habitat types associated with the on-going nearshore benthic monitoring program (NOGAP Subproject B.2.3).

The field component of this study has been completed, and data reports are presently being prepared. It was anticipated that approximately 23 data reports of field work carried out as part of NOGAP Project B.2 (Beaufort Shelf Fish Habitat Research; Beaufort Nearshore Benthic Monitoring) will be produced over the next 2 years and that the technical reports will be completed by 1992. Reductions in funding and resources have set back completion dates for an undetermined period of time.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this study will provide basic descriptive information on biological communities of the Mackenzie Shelf and will contribute to an increased understanding of energy flow in the Beaufort Sea and the trophic relationships among components of the system.

The study is relevant to Links 7, 8 and 9a of Hypothesis 6. These links suggest that a reduction in the abundance of zooplankton and epibenthos (prey of Arctic cod) will result in reduced numbers and size of cod, and that this in turn will reduce the population size of ringed seals.

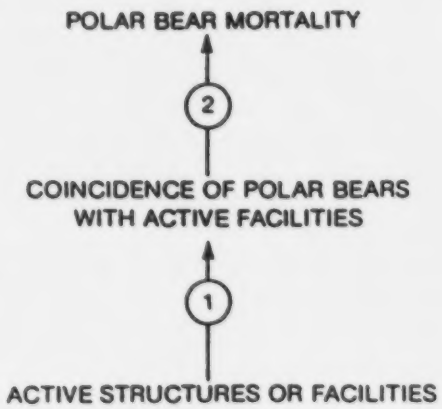
This study may also provide insight into trophic relationships relevant to Hypothesis No. 19, "Dredging and deposition of spoil will reduce the bearded seal population". This could presumably occur indirectly as a result of dredging-related reductions in the benthic prey organisms of some fish species, which could then result in fewer and smaller fish being available for consumption by bearded seals. The present studies on the feeding habits of fish will lead to a better understanding of the plausibility of such a functional relationship.

HYPOTHESIS NO. 7

The presence of active facilities will result in increased polar bear mortality.

FIGURE 7-1

POTENTIAL EFFECTS OF ACTIVE FACILITIES ON POLAR BEARS



LINKAGES

1. Polar bears will encounter active structures or facilities.

2. Polar bears that approach offshore structures have to be controlled, and this will result in the need to destroy some bears.

BEMP IMPACT HYPOTHESIS NO. 7

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 7

After examining this hypothesis and its linkages, the 1985 working group concluded that both remain valid. Personnel on drill rigs continue to report the coincidence of bears with offshore structures but few bears are killed. Considerable progress has been made in the development of methods for detecting and deterring bears. Recent research on detection techniques has focussed on microwave and infrared instruments, while polar bear deterrant studies have involved further evaluation of the effectiveness of the rubber bullet gun, plastic slugs fired from a shotgun, and sound-producing devices.

The participants in the 1985 workshop re-confirmed support for research on polar bear detection and deterrant techniques, as well as the possible use of certain detection instrumentation developed for censusing marine mammals. There was considerable concern regarding the unknown status of the Alaskan subsistence polar bear harvest, which is focussed on females with cubs. In the absence of appropriate data on this harvest, it was emphasized that declining numbers of polar bears in the Beaufort region might be incorrectly attributed to either the Canadian harvest or industrial impacts.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 7-1

TITLE:	Bear Detection and Deterrent Research/Education
PRINCIPAL INVESTIGATOR:	P.A. Gray
AFFILIATION:	Department of Renewable Resources Government of NWT, Yellowknife, NWT
FUNDING SOURCES:	Various gov. agencies (EMR, INAC, Manitoba Dept. National Resources, CWS, NOGAP) and industry (Mobil, B.P. Minerals, Gulf, Dome, Petro-Canada, Cominco, ESSO)
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	7

BRIEF PROJECT DESCRIPTION

In the late 1970s, the NWT Wildlife Service (NWTWS) began research on methods to reduce bear-human conflicts and interactions, and in 1981, initiated a formal bear detection and deterrent program. To date, many detection and deterrent techniques have been identified and tested. Detection systems tested to date include a proximity detection unit, trip-wire fence system, microwave

motion detection unit, dogs, bear monitors, and infra-red detection units, while bear deterrent methods tested include warning shots/cracker shells/airhorns, vehicles (snow, 3 wheel, helicopters) rubber bullets, flare cartridges, electric fences, and 12-gauge plastic/rubber slugs. Practicality, effectiveness, advantages and limitations of each method have been evaluated, and thus an appropriate system can be chosen for a specific site. Testing of the various systems and methods is ongoing.

One of the more promising deterrent techniques is the 12-gauge, pump-action shotgun, using a three-slug system (cracker shells, plastic slugs, lead slugs). Bears can be deterred using the cracker shells and plastic slugs, and if necessary, destroyed using the lead slug. This system provides personnel handling bear problems more options and should reduce the number of bears that must be destroyed. This system was recently described by Peter Clarkson, GNWT, Inuvik.

As bear detection and deterrent research is completed, it is important that this information be communicated to people living and working in regions inhabited by bears. In response to this need, three initiatives have been developed by the GNWT: (1) production of a "Safety in Bear Country" reference manual in 1985, (2) the "Safety in Bear Country" workshop program, and (3) operational plans for problem bear sites. An international conference on bear-people conflicts was recently held in Yellowknife, NWT (April 1987).

The success of this research has prompted proposals by the NWTWS for expansion of similar studies and workshop programs throughout regions inhabited by bears.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 7, which states that "the presence of active facilities will result in increased polar bear mortality" continues to be considered valid. This hypothesis suggests that polar bears will be attracted to offshore structures (Link 1), and that the need to maintain worker safety could necessitate the destruction of some animals (Link 2). Research and communication on deterrent and detection systems will reduce the number of bear-human interactions and reduce mortality of bears that do become involved in these interactions.

BEMP IMPACT HYPOTHESIS NO. 7

BEMP PROJECT OVERVIEW NO. 7-2

TITLE:	**Status of Polar Bears in Alaska**
PRINCIPAL INVESTIGATOR:	S. Amstrup
AFFILIATION:	U.S. Fish and Wildlife Service, Anchorage, Alaska
FUNDING SOURCES:	U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, and others
EXPECTED COMPLETION DATE:	Ongoing
RELEVANT BEMP HYPOTHESIS NO.:	6, 7 and 9

BRIEF PROJECT DESCRIPTION

The U.S. Fish and Wildlife Service (USFWS) is presently responsible for the conservation and management of polar bears in Alaska. The principal objectives of their research program are to determine: (1) the size of Alaskan polar bear populations; (2) movements and distribution patterns; and (3) the location of maternity denning areas. Research on Alaskan bears has been ongoing since 1966 involving mark-recapture and, more recently (1983-1987), radio and satellite telemetry studies with adult females.

Together with studies in the Canadian Beaufort, the Alaskan studies indicate that bears from Cape Bathurst to Point Barrow belong to the same breeding population, although subpopulations apparently exist.

The size of the Beaufort Sea population was estimated using four methods: two mark-recapture methods, and two methods based on sightings per hour of flight. Results using each method suggest that the population size is about 1800 bears and is believed to be stable.

In 1986, the emphasis of the project was shifted from tracking through radio-telemetry to tracking by satellite telemetry. The geographic position of 20 satellite-collared adult female polar bears was monitored every three days. The success of these satellite telemetry studies reduced the effort directed at the mark-recapture program.

The 1987 research focussed on the location of maternity denning areas. It was originally hypothesized that a majority of dens would be situated on pack ice. The distribution of 16 new maternity dens located in 1987 support this theory. A subsequent study was initiated to determine the distribution of land-based dens using circumstantial den evidence (tracks, etc.).

The 1986 and 1987 studies included an expanded study of the predator/prey interactions between the bears and seals. The data obtained from these studies have not been analysed and research is continuing.

BEMP IMPACT HYPOTHESIS NO. 7

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This research provides information indirectly relevant to Hypothesis No. 6 and No. 7. The results of the Alaskan research are significant because they show that the Beaufort Sea polar bear population extends from Point Barrow to near Cape Bathurst. Therefore, any activity in Alaska that adversely affects this population could lead to reduced numbers of bears in the Canadian Beaufort (hence a potential for reduced harvest), and perhaps the perception that reduced harvest was due to offshore hydrocarbon development in the Canadian Beaufort. Although polar bear harvests are regulated in Canada, this is not the case in the U.S. There is presently a concern in Alaska that the unregulated subsistence harvest of polar bears is concentrating on female bears and cubs (which tend to use nearshore areas) to such an extent that it may begin to adversely affect the population if the harvest was to increase further.

BEMP PROJECT OVERVIEW NO. 7-3

TITLE:	**Assessment of the Polar Bear Population in the Eastern Beaufort Sea**
PRINCIPAL INVESTIGATOR:	I. Stirling
AFFILIATION:	Canadian Wildlife Service, Edmonton, Alberta
FUNDING SOURCE:	NOGAP, CWS, GNWTWS, Yukon Wildlife Branch, PCSP
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	6, 7, 8 and 9

BRIEF PROJECT DESCRIPTION

The objectives of this three-year study were to determine the size of the polar bear population in the eastern Beaufort Sea and Amundsen Gulf, the demographic and reproductive parameters of the population, and the distribution of subpopulations. These data were compared with results from a similar study conducted in the region from 1971-1979. A further objective was to evaluate effects of offshore hydrocarbon exploration activities on the polar bear population.

It will be difficult to achieve this latter objective because of the compounding influence of recently increased quotas in Canada, unrestricted (and variably recorded) harvest practices in Alaska, and because no experimental procedure to evaluate cause and effect could be undertaken as part of the research.

The study was initiated in spring 1985, and was completed in 1987. A total of 608 bears (290 males and 318 females) were handled in these years; each bear was tagged, measured and aged. Data analysis is in progress. The population

is estimated between 1300 and 2100 polar bears, with an indication of two geographically-separated subpopulations. Preliminary analysis suggests that the population size and reproductive parameters have remained constant since the 1970s. The data base for the study will be expanded with mark-and-recapture data collected by the Yukon Wildlife Branch, GNWTWS, and USFWS, with radio-tracking data collected as part of Project 7-2, published information, incidental sightings by personnel on industry ships, and harvest data.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project will provide background information that is relevant to all hypotheses concerning polar bears (Hypothesis No. 6, 7, 8 and 9). Detection of changes in the size, demography, reproductive condition, body condition, and distribution of subpopulations in the polar bear population has clear relevance to Hypothesis No. 7. If the polar bear population were found to be changing, quotas would likely be adjusted and this could then affect harvest levels. Because bears will be directly examined during this work, information about oiled bears relevant to Hypothesis No. 9, "Chronic/episodic oil spills resulting from normal hydrocarbon development activities within and adjacent to the marine environment will result in localized mortality of polar bears", may also become available.

BEMP PROJECT OVERVIEW NO. 7-4

TITLE:	Attraction of Polar Bears (*Ursus maritimus*) to Offshore Drilling Sites in the Eastern Beaufort Sea.
PRINCIPAL INVESTIGATOR:	I. Stirling
AFFILIATION:	Canadian Wildlife Service, Edmonton, Alberta
FUNDING SOURCE:	DIAND, CWS, PCSP, and APOP
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	7

BRIEF PROJECT DESCRIPTION

The objective of this study was to determine whether polar bears are attracted to drill rigs and will be judged to represent a threat to humans at these sites, and consequently will have to be deterred or destroyed.

Wildlife observations from several offshore hydrocarbon exploration sites were examined to evaluate this hypothesis. The recorded observations provided information on the season, duration, and frequency of polar bear visits as well as ice conditions and corresponding seal abundance in the area.

BEMP IMPACT HYPOTHESIS NO. 7

The presence of drill rig sites changes the sea-ice habitat, which attracts ringed and bearded seals to the area. Successful hunting in these areas of higher seal abundance results in more bears being attracted to drill rig sites. This positive reinforcement may result in bears returning to these sites in the future and remaining there for longer periods. Remaining around these sites for longer periods of time may result in polar bears becoming habituated to human presence and they may lose their fear of man. Detection and deterrent programs will have to be initiated if bears do become habituated to humans and present a threat.

A more detailed and scheduled recording of wildlife observations was suggested to increase the understanding of the influence of permanent offshore drilling platforms on the distribution of seals and polar bears. This information combined with more detailed data on environmental conditions could help to predict the occurrence of polar bears around offshore exploration facilities.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is directly relevant to Hypothesis 7 which states that "the presence of active facilities will result in increased polar bear mortality". The two links of this hypothesis suggest that polar bears will be attracted to offshore structures, and the need to maintain worker safety would then necessitate the destruction of some animals.

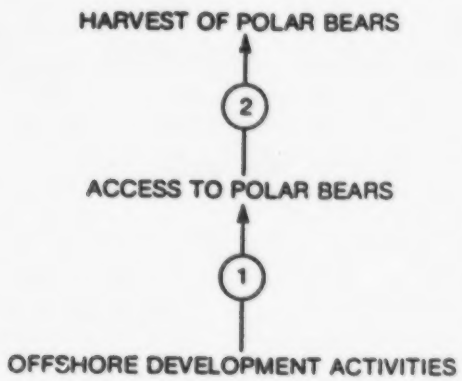
The polar bear population is not under threat as only four bears have been shot in the last five years. There is concern, however, that if the number of drill rig sites increases, the need to protect human life and property may reduce polar bear populations.

HYPOTHESIS NO. 8

Offshore development activities will reduce the harvest of polar bears.

FIGURE 8-1

POTENTIAL EFFECTS OF OFFSHORE DEVELOPMENT ON POLAR BEAR HARVEST



LINKAGES

1. Hunter access to polar bears will be reduced because offshore development will cause bears to move farther offshore and/or create physical barriers to Inuit travel on the ice.

2. Reduced access to polar bears will lead to reductions in the Inuit harvest of polar bears.

BEMP IMPACT HYPOTHESIS NO. 8

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 8

Participants in the 1984 workshop concluded that this hypothesis was unlikely and, therefore, did not warrant any specific research or monitoring. The 1985 workshop group agreed with this overall conclusion and recommendation at the current level of industrial activity in the Beaufort Sea. During the period when polar bears are harvested, icebreaker tracks would quickly re-freeze and would unlikely impede hunter travel over the landfast ice. However, as in Hypothesis No. 7, the group concluded that any future monitoring efforts would be hampered by the lack of data on the Alaskan subsistence harvest of polar bears. Participants indicated that without adequate information on this hunt, it will not be possible to determine the factors responsible for any future declines in numbers of polar bears.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

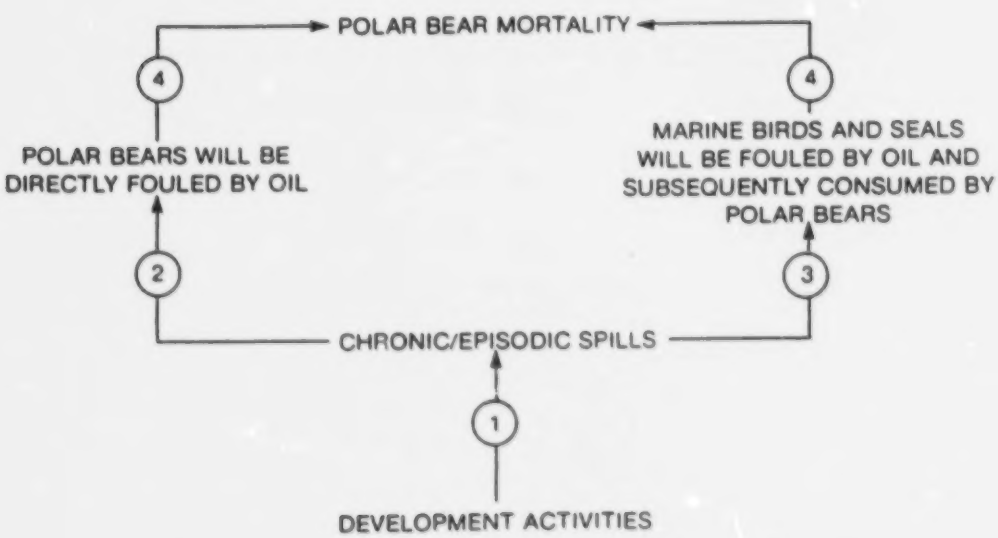
There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 9

Chronic/episodic oil spills resulting from normal petroleum hydrocarbon development activities within and adjacent to the marine environment will result in localized mortality of polar bears.

FIGURE 9-1

POTENTIAL EFFECTS OF CHRONIC/EPISODIC OIL SPILLS RESULTING FROM NORMAL PETROLEUM HYDROCARBON DEVELOPMENT ACTIVITIES WITHIN AND ADJACENT TO THE MARINE ENVIRONMENT ON POLAR BEARS



LINKAGES

1. Development activities will result in chronic/episodic spills.
2. Chronic spills will result in the direct fouling of polar bears.
3. Chronic spills will result in the direct fouling of marine birds and seals that are consumed by bears.
4. Mortality of bears will occur if oil is contacted or ingested.

BEMP IMPACT HYPOTHESIS NO. 9

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 9

Information presented by petroleum industry representatives and regulatory agencies during the 1985 workshop indicated that chronic oil spills associated with exploration activities are both infrequent and relatively small. Nevertheless, research conducted with captive polar bears has shown that this species is extremely sensitive to oil contact and/or digestion. As a result, the workshop group endorsed and encouraged the publication and implementation of an "Action Plan for Protection of Polar Bears in the Event of a Major Oil Spill". This was prepared by federal, territorial and provincial polar bear biologists and submitted to the Polar Bear Advisory Committee in June 1986.

Workshop participants in 1985 also recommended that a plan be developed to facilitate effects monitoring of "spills of opportunity". Such a plan should (1) identify a scientific team to respond to spills, and (2) provide a description of what and how monitoring should be initiated (including associated research) in the event of a spill. The group concluded that revisions to this or other plans may be necessary at a later date to address opportunistic research/monitoring, as well as to consider other species of marine mammals.

A research program to determine the behavioural responses of polar bears to oil-covered waters and oil-contaminated prey was discussed during the 1985 workshop. However, it was concluded that this research would encounter considerable public and political opposition and, therefore, was considered untenable.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

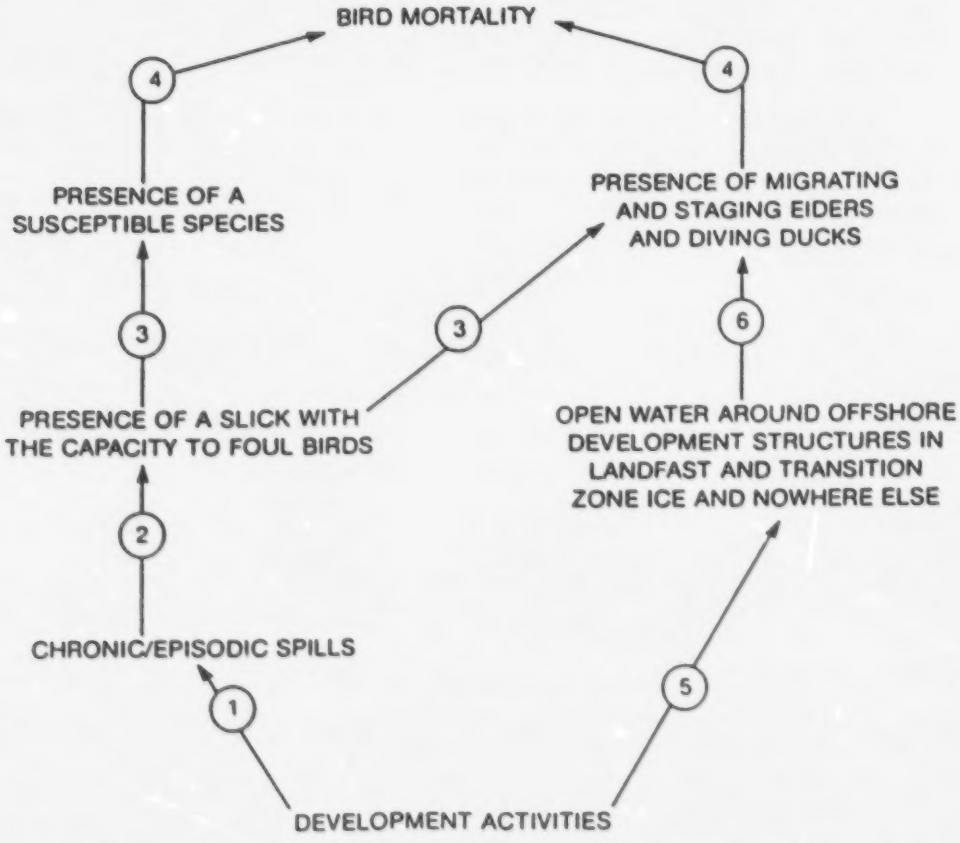
There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 10

Chronic (episodic) oil spills resulting from normal petroleum hydrocarbon development activities within and adjacent to the marine environment will result in local mortality of certain species of birds.

FIGURE 10-1

POTENTIAL EFFECTS OF CHRONIC (EPISODIC) OIL SPILLS RESULTING FROM NORMAL PETROLEUM DEVELOPMENT ACTIVITIES ON BIRDS



BEMP IMPACT HYPOTHESIS NO. 10

LINKAGES

1. Development activities will result in chronic (episodic) spills of petroleum hydrocarbons.

2. Where chronic (episodic) spills occur, slicks with the capacity to foul birds will be present under certain conditions.

3. Susceptible bird species will co-occur in space and time with the presence of a slick.

4. Mortality of birds will occur following slick contact.

5. Thermal discharges under or onto the ice from offshore production facilities will enhance melting and formation of open water around structures (Hypothesis No. 11, Link 3, 1983-84 BEMP report).

6. Eiders and other diving ducks are attracted to open water areas during migration and staging (Hypothesis No. 11, Link 4, 1983-84 BEMP report).

BEMP IMPACT HYPOTHESIS NO. 10

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 10

This hypothesis was combined with Hypothesis No. 11 during the 1985 workshop because it was concluded that the latter was simply a specialized case of a more general hypothesis pertaining to the effects of chronic oil spills on bird populations. Several of the original linkages in Hypothesis No. 11 were considered invalid or improbable and, therefore, were removed during this consolidation.

Much of the discussion at the 1985 workshop focussed on the need to monitor and record the incidence of oiled birds (or other wildlife) to document the effects of incidental oil spills. Consensus was not reached on this question largely because there have been no reports of bird mortality to date following chronic spills in the region and this is not an area of significant concern in other oil-producing regions of the world. It was concluded that oil spill reports should continue to include any observations of oiled wildlife. With possible future hydrocarbon production, chronic oil spills may increase in frequency and volume from present levels, and this may then justify implementation of a systematic monitoring program.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 11

Oil slicks in open water areas around offshore structures during normal periods of ice cover will cause increased mortality of eiders and diving ducks.

This hypothesis was combined with Hypothesis No. 10 during a previous workshop, and no longer exists in its original form.

HYPOTHESIS NO. 12

Frequent low altitude aircraft flights over staging birds will cause increased overwinter mortality.

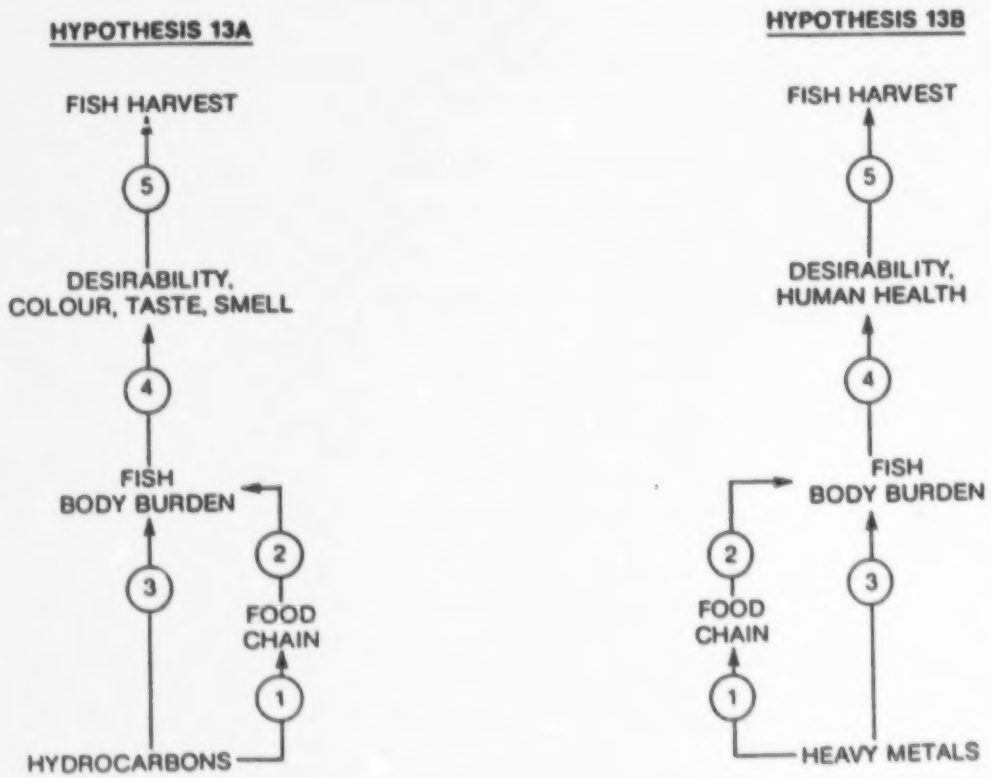
During previous workshops, it was concluded that this hypothesis was invalid.

HYPOTHESIS NO. 13

Shorebases and shallow-water production facilities will release hydrocarbons and heavy metals at sufficient levels such that fish harvest will be reduced through tainting and heavy metal accumulations.

FIGURE 13-1

POTENTIAL EFFECTS OF RELEASE OF HYDROCARBONS AND HEAVY METALS ON FISH HARVEST



BEMP IMPACT HYPOTHESIS NO. 13

LINKAGES FOR HYPOTHESIS 13A

1. and 3. Hydrocarbons in water and sediments will enter fish and prey organisms of harvested fish species.

2. Hydrocarbons can be passed through food chains.

4. Desirability of fish is decreased as a result of increases in body burden of hydrocarbons.

5. Decreased desirability will decrease fish harvest.

LINKAGES FOR HYPOTHESIS 13B

1. and 3. Heavy metals from water and sediments will enter fish and prey organisms of harvested fish species.

2. Heavy metals can be passed through food chains.

4. Human health and desirability of fish can be affected by increases in heavy metal concentrations.

5. Decreased desirability will decrease fish harvest.

BEMP IMPACT HYPOTHESIS NO. 13

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 13

During the 1985 workshop, it was concluded that Hypothesis No. 13 was valid and was an area of relatively high profile with respect to BEMP, particularly those links leading from chronic hydrocarbon exposure to the tainting of fish. Federal government agencies have collected data on hydrocarbon and trace metal levels in sediments and biota in several areas of the Beaufort Sea. It was recommended that comparative analyses of the data from these studies be conducted to identify any areas where elevated body burdens of trace metals and hydrocarbons in benthic fauna or fish can be correlated with contamination of sediments. It was also recommended that a program of time series measurements of hydrocarbons in fish be initiated in Tuktoyaktuk Harbour.

In 1985, a study to detect effects of potential contaminants in Tuktoyaktuk Harbour was initiated by Environment Canada. The main findings of this three-year study are presented in Project Overview 13-2.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 13-1

TITLE:	Beaufort Sea Oceanography (NOGAP Project B.6)
PRINCIPAL INVESTIGATORS:	R.W. Macdonald
AFFILIATION:	Department of Fisheries and Oceans (Institute of Ocean Sciences)
FUNDING SOURCE:	NOGAP/INAC
EXPECTED COMPLETION DATE:	1991
RELEVANT BEMP HYPOTHESIS NO.:	1, 16, 13, 20

BRIEF PROJECT DESCRIPTION

This project is directed at testing the hypothesis that naturally-occurring hydrocarbons on the Beaufort Sea shelf are carried predominantly by particulate and colloidal material and in so doing describe the transport and fate of hydrocarbons over the Beaufort Sea Shelf. The testing of this hypothesis requires a multidisciplinary thrust as primary productivity, bacterial activity and physical transport processes all influence the partitioning of hydrocarbons among particulate, colloidal, dissolved and biotic environmental compartments. The ultimate objective of the project is to understand the natural hydrocarbon distributions and primary productivity in the oil exploration zone of the Mackenzie River Estuary.

BEMP IMPACT HYPOTHESIS NO. 13

The field component of this study has spanned two years and has included the collection of samples and data in both open water and during winter. Measurements and sample collections have included salinity, temperature, nutrients (reactive silicate,phosphate, nitrate plus nitrite), oxygen isotopes, total suspended solids, particulate organic carbon and nitrogen, chlorophyll a, productivity, total carbon dioxide, sediments, phytoplankton, bacterial enumeration, particle identification (by scanning electron microscopy), light intensity, photosynthetically-active radiation, and zooplankton. In addition, satellite imagery was obtained to study regional water temperature, turbidity and ice distributions occurring during the collection of samples at sea. Bulk suspended sediment samples were obtained using sequential and non-sequential sediment traps. Current meter recordings supplemented the physical measurements. Samples were obtained along transects as shown in Figures 2 and 3.

To date, the project has produced numerous outputs in the form of reports and publications. A list of currently available reports is given below with a brief description of the contents of each. As several reports are currently in preparation, the reader should consider the list below incomplete. Inquiries for the status of on-going studies and new reports should be directed to the NOGAP co-ordinator at the Institute of Ocean Sciences, Pat Bay, B.C.

1. Macdonald, R.W., K. Iseki, E.C. Carmack, D.M. Macdonald, M.C. O'Brien and F.A. McLaughlin. 1988. Data Report: NOGAP B.6; Beaufort Sea Oceanography, September, 1986. Can. Data Rep. Hydrogr. Oc. Sci. 58., v + 68 pp.

   This data report provides a listing of supporting geochemical measurements to NOGAP B.6, including salinity, temperature, nutrients (silicate, phosphate and nitrate), oxygen isotopes, chlorophyll a, total suspended

BEMP IMPACT HYPOTHESIS NO. 13

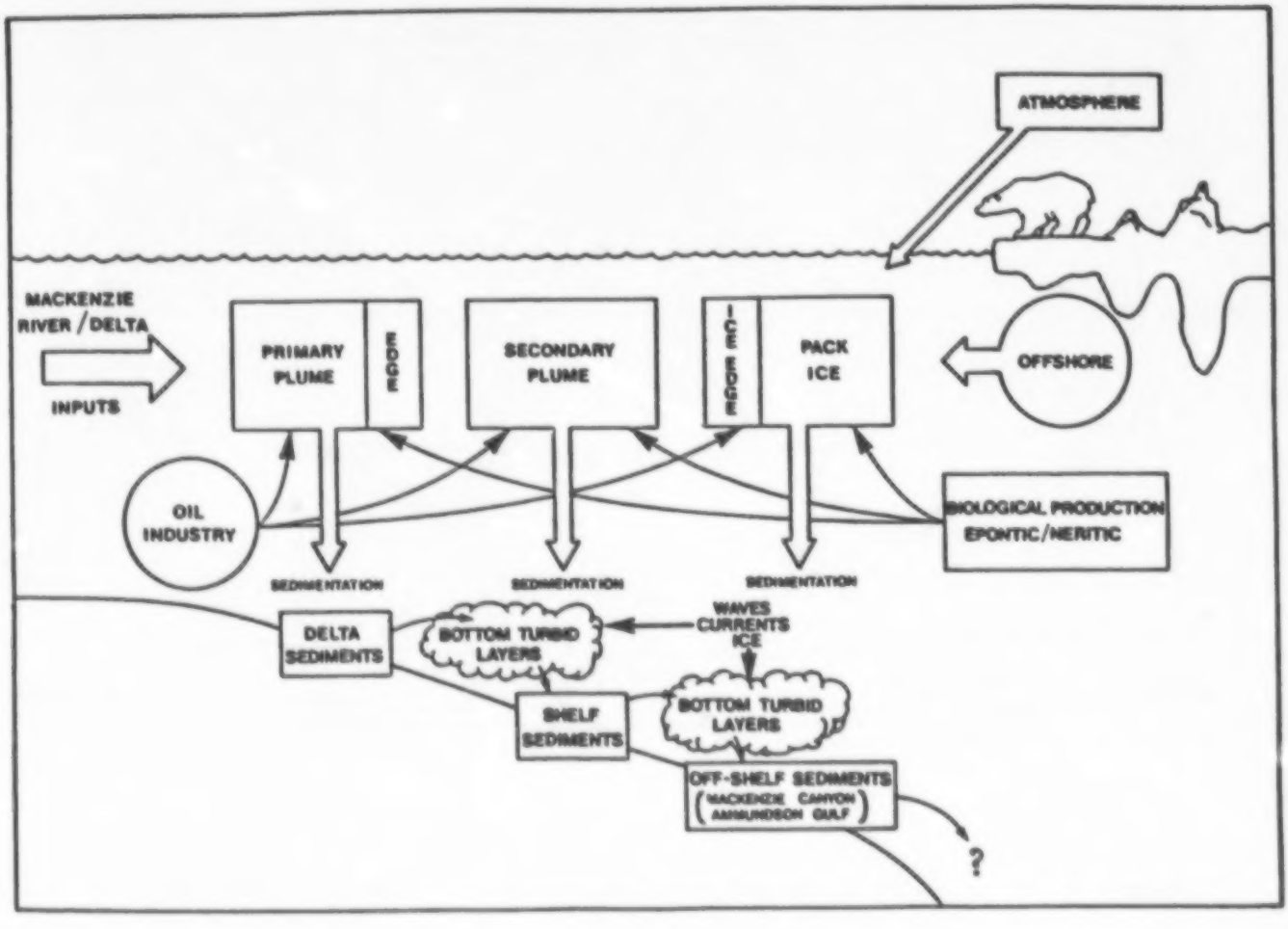


Figure 1. Box model for input/output of materials to the oil exploration zone of the Beaufort Sea Shelf.

BEMP IMPACT HYPOTHESIS NO. 13

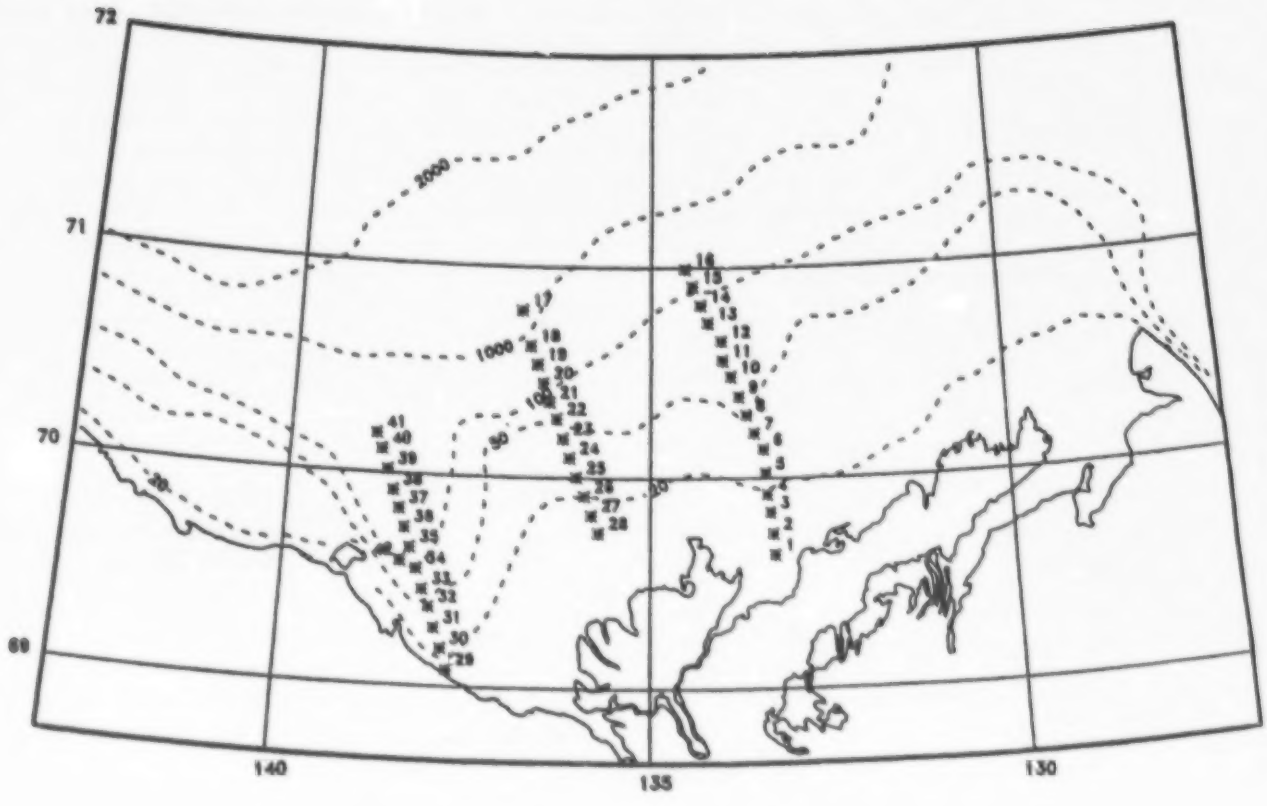


Figure 2. Station locations on the Beaufort Sea Shelf for 1986 sampling.

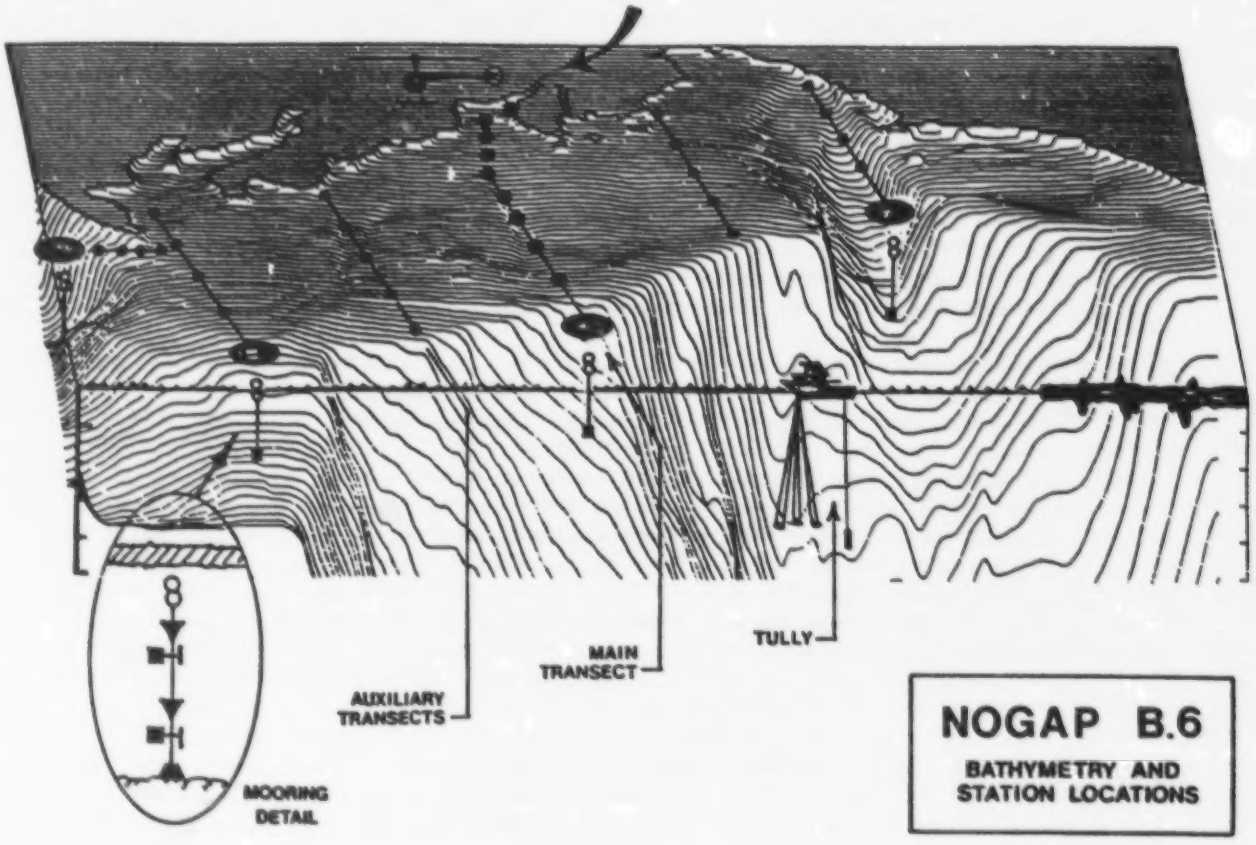


Figure 3. Station locations on the Beaufort Sea Shelf for 1987 sampling.

solids, particulate organic carbon and nitrogen, and bacterial enumeration obtained as a result of the cruise of the Arctic Ivik to the southern Beaufort Sea in September, 1986.

2. Cuypers, L.E., A.W. Blaskovich, E.C. Carmack and R.W. Macdonald. 1988. NOGAP B.6; Physical Data Collected in the Beaufort Sea, September 1986. Can. Data Rep. Hydrogr. Oc. Sci. 59, v + 149 pp.

This data report provides a listing of supporting physical oceanographic data to NOGAP B.6 including temperature, salinity, light transmission and attenuation, density, departure from freezing point, and dynamic height anomaly obtained as the result of the cruise of the Arctic Ivik to the southern Beaufort Sea in September, 1986.

3. McCullough, D., R.W. Macdonald, K. Iseki and E.C. Carmack. 1988. NOGAP B.6; Volume 1: Beaufort Sea Current Measurements, March - August 1987. Can. Data. Rep. Hydrogr. Oc. Sci. 60 (1), v + 42 pp.

Four subsurface taut-line moorings were deployed during the spring of 1987 along the 200-metre isobath in the Beaufort Sea. Each mooring comprised two current meters and a sequential sediment trap. One current meter was located as close to the surface as predicted ice keel depths would allow and the other was placed 50 metres above the seafloor near the sediment trap. The moorings were recovered during the open water season in 1987. This report provides a summary of the data obtained in the deployment in the form of time series plots (at fixed depths) of temperature, salinity, current speed and direction, and light transmission.

4. Macdonald, D.M., L.E. Cuypers, D. McCullough, E. Carmack and R.W. Macdonald. 1988. NOGAP B.6; Volume 2: Physical Data Collected in the Beaufort Sea, March - June 1987. Can. Data Rep. Hydrogr. Oc. Sci. 60(2), v + 157 pp.

Chemical, biological and physical water properties were measured in 1987 along a transect extending from Tuktoyaktuk to the Beaufort Sea shelf break. Measurements were made through the ice from March through to breakup in June. This report includes a summary of the supporting physical oceanographic data (to NOGAP B.6) including temperature, salinity, light transmission and attenuation, density, departure from freezing point, and dynamic height anomaly. Also included are physical measurements made in the nearshore zone to investigate the under-ice structure of the Mackenzie River plume.

5. McCullough, D., R.W. Macdonald, K. Iseki and E.C. Carmack. 1988. NOGAP B.6; Volume 3: Beaufort Sea Current Measurements. September 1987 - March 1988. Can. Data Rep. Hydrogr. Oc. Sci. 60(3). v + 37 pp.

   This report provides data for the period September 1987 to March 1988 analogous to those obtained at the same four locations during March - August 1987 (see McCullough et al. 1988 above).

6. Macdonald, R.W., K. Iseki, M.C. O'Brien, F.A. McLaughlin, D. McCullough, D.M. Macdonald, E.C. Carmack, H. Adams, M. Yunker, G. Miskulin and S. Buckingham. 1988. NOGAP B.6; Volume 4: Chemical Data Collected in the Beaufort Sea, Summer, 1987. Can. Data Rep. Hydrogr. Oc. Sci. 60(4), v + 103 pp.

   Chemical, biological and physical water properties were measured on 5 transects extending from inshore waters to the shelf break and at one deep station (3500 m) in the southwestern Canada Basin during a cruise of the C.S.S. John P. Tully, July - September, 1987. This data report provides a summary of data obtained from bottle samples and includes salinity, temperature, dissolved oxygen, phosphate, nitrates, reactive silicate, chlorophyll a, total suspended solids, and particulate organic carbon and nitrogen.

7. Acreman, J. 1987. Phytoplankton species with quantitative data on cell numbers, cell volume and cell carbon from samples collected during September 9 - 14, 1986 in the Beaufort Sea. 10 pp. + Appendices.

   Species occurrence and abundance are reported for 35 phytoplankton samples collected during the September 1986 cruise of the Arctic Ivik. Cell volumes were determined on 17 samples from which data cell carbon estimates were made.

8. Hodgins, D.O. 1988. Sediment-Storm Interaction Study. A report prepared by Seaconsult Marine Research Ltd. Vancouver, B.C. vi + 94 pp. + Appendices.

   This report provides details of a project (1) to develop an instrument to monitor storm-induced sediment resuspension and transport together with synchronous changes in porewater pressure in surficial sediments; (2) to deploy the instrument in the Beaufort Sea to measure changes in fine sediment concentration during a moderate intense autumn storm capable of resuspending bottom material in the silt size range; and (3) to develop a model to predict suspended sediment distributions and sediment transport associated with a storm-induced resuspension event. An instrument was deployed off the mouth of Kugmallit Bay between September 1 and September 7, 1987 in conjunction with two bottom-mounted directional wave gauges. Sediment samples and cores were also acquired. The report provides a series of observations on the characteristics of sediment resuspension

during a storm September 4 - 5, 1987, a discussion or pore water pressure measurements obtained during the deployment and a discussion of the results obtained following application of an equilibrium concentration model to the resuspended particle data obtained during the storm event.

9. Jasper, S. 1988. Phytoplankton Productivity in the Mackenzie Estuary of the Beaufort Sea, 1987. Prepared by S. Jasper Consulting, Vancouver, B.C., iii + 24 pp.

This report provides a summary of a study of phytoplankton productivity conducted in the Southern Beaufort Sea during the period April 5 - Sept. 2, 1987. The study combined an incubator method for determination of the phytoplankton photosynthesis vs. light (P-I) response, and a computer model that incorporated these and other data to produce estimates of areal phytoplankton productivity. Data are given for both ice-covered and ice-free portions of the year.

10. Borstad, G.A., M.R. MacNeill and L.L. Armstrong. 1988. The 1987 Seasonal Ice Cycle in the Canadian Beaufort Sea. Prepared by G.A. Borstad Associates Ltd., Sidney, B.C. iv + 44 pp. + Appendices.

The objective of this study was to provide a time series of ice behaviour in the Beaufort Sea for 1987 that could be compared to physical, chemical and biological oceanographic data collected from inter-disciplinary cruises and fixed mooring stations. The report provides:

(1) a qualitative description of the seasonal ice cycle in the Beaufort Sea in 1987, noting formation of polynyas, changes in offshore lead structure, break-up of landfast ice, development of open water areas, and the sequence of freeze-up.

(2) a comparison of 1987 meteorological data from Herschel Island, Pelly Island and Cape Bathurst with the ice dynamics.

(3) a time series of approximate ice coverage data at four fixed sediment trap stations;

(4) a comparison of ice behaviour in 1987 with other years to establish whether it was an average or an extreme year in terms of the seasonal ice cycle.

11. McCrimmon, R.C. and P.F. Hamblin. 1988. Numerical experiments on the gravitational collapse of stratified water columns including compressibility effects. Prepared by National Water Research Institute (Contribution 88-33). Lakes Research Branch. Burlington, Ontario. 7 pp. + Appendices.

    The study was undertaken to improve the current understanding of the formation of Arctic Ocean waters as Beaufort Sea shelf waters mix with open Arctic Ocean waters. The report presents the results of two gravitational collapse experiments to demonstrate the effects of compressibility and non-linear dependence of density on temperature on the formation of water masses in the ocean.

12. Whitehouse, B.G. and P.J. Wangersky. 1988. Provision of hydrocarbon measurements for the NOGAP B.6 Programme: Phase partitioning by crossflow techniques. Prepared by Dept. Oceanography, Dalhousie University. ii + 20 pp.

    This report provides details of a study to investigate the solid/liquid phase partitioning of hydrocarbons in the Mackenzie River Estuary. The study involved deployment of a crossflow filtration apparatus capable of physically separating the colloidal and dissolved fractions of a water sample. Data for dissolved organic carbon and particulate organic carbon are given.

13. Whitehouse, B.G. 1988. Organic carbon and fi hydrocarbons in the colloidal fraction: Analysis of data obtained from the Mackenzie River and Beaufort Sea. iii + 33 pp.

    This report presents data on hydrocarbon content of colloids and an interpretation of the available colloid and relevant physical oceanographic information for samples collected in September 1987. It is a follow-on of the contribution by Whitehouse and Wangersky noted above.

14. Macdonald, R.W. and P.E. Erickson. 1987. The distribution of nutrients in the southeastern Beaufort Sea: Implications for water circulation and primary production. J. Geophys. Res. 92 (C3), 2939.

    This paper presents an interpretation of nutrient data obtained during the Beaufort Sea Project of 1974 and 1975. Estimates of new productivity based on nutrient budgets show that the presence of turbid water and ice cover during 1974 (a heavy ice year) had reduced productivity by about 30% over that which occurred in 1975, a year with much open water. Nutrient characteristics of the vertical water column in the southern Beaufort Sea are given and the significance to the surface waters of the Arctic Ocean in general of regeneration of nutrients over the shelf is discussed.

15. Iseki, K., R.W. Macdonald and E. Carmack. 1987. Distribution of particulate matter in the southeastern Beaufort Sea in late summer. Proceedings of the National Institute of Polar Research Symposium on Polar Biology No. 1.Tokyo, December 1987.

    This paper provides an interpretation of particulate matter results obtained along three transects during the September 1986 cruise of the Arctic Ivik in the southern Beaufort Sea. The paper discusses sources of particulates to the water column and the distribution of particulates in the water column in relation to other characteristics such as salinity, POC and light transmission characteristics.

16. Buckley, J.R. and W.P. Budgell. 1988. Meteorologically Induced Currents in the Beaufort Sea. Institute of Ocean Sciences, Pat Bay, B.C. Draft Report dated April 21, 1988. 53 pp. + Appendices.

    The purpose of this study was to address the problem of providing an adequate data base from which to predict extreme currents by combining a state-of-the-art numerical model of ocean circulation on the Beaufort continental shelf with a well documented data base of quantitatively determined storms in the Beaufort Sea region and with all data collected in the period which the storm database spans. The model appears to provide a fairly accurate description of these currents on the continental shelf portion of the Beaufort Sea whose variability in the two to five day period is a result of meteorological forcing. As such it can provide useful insight into the influence of wind-driven circulation on the transport paths of resuspended sediments or discharge streams.

A major emphasis of project B.6 was hydrocarbon chemistry. Although some hydrocarbon samples have been analysed, few results are available. It is expected that several years will be required to analyse, interpret and publish the data. It is anticipated that the project reports will provide important information on the following subjects:

(1) the primary form of hydrocarbon found in the water column and the mechanism of its transport on the shelf;

(2) the amount of anthropogenic hydrocarbon transported to the shelf by atmospheric pathways from Europe.

(3) the amount of natural hydrocarbon produced over the Beaufort Sea shelf.

(4) the amount of carbon turned into food during the growth season, where it takes place and whether there are critical areas.

(5) the amount of natural hydrocarbon discharged onto the shelf by the Mackenzie River.

(6) the type of bacterial populations on the shelf that can degrade hydrocarbon and the rate at which they can do it.

(7) the ability of storms to provide a seed microbial population to decompose hydrocarbon.

(8) the transport pathways, cycles and fate of hydrocarbons on the Beaufort Sea Shelf.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

A primary function of BEMP is to predict impact on the environment of the Beaufort Sea Shelf as the result of offshore hydrocarbon exploration/development activities. One way of doing this for industrial discharges of hydrocarbons is to study and model processes governing natural distributions of the same compounds. The project described above will probably allow this to occur. In addition, this study will provide the first regional, interdisciplinary data set that is internally consistent. Refinements to budgets and fluxes for C, N, P, particulates, freshwater, hydrocarbons and heat will be possible. Photosynthesis will be amenable to modelling. The likely contributors and the magnitude of the contributions of sediments, particulates, water column, ice, atmosphere, algae, zooplankton, and river water to the total hydrocarbon budget should be amenable to assessment. It should also be possible to model the Mackenzie River/Mackenzie Estuary/Beaufort Shelf for its dynamics with respect to the transport and control of water properties over the shelf with particular emphasis on the near shore zone associated with oil exploration. In an overall sense, the research being conducted in this project should allow known or anticipated anthropogenic inputs to be put into the proper spatial, physical and temporal context of the natural processes occurring in the ecosystem. This should lead to more realistic evaluation and prediction of environmental effects associated with offshore oil activities and better prediction of recovery patterns of the ecosystem following large-scale accidental releases of hydrocarbons, should these occur. The information obtained in this study should also aid in the interpretation of feeding, migration and spatial patterns of Beaufort Sea biological resources, and in aiding in the realistic assessment of the vulnerability of certain biological resources to the effects of contaminants released to the Beaufort Sea Shelf.

BEMP IMPACT HYPOTHESIS NO. 13

BEMP PROJECT OVERVIEW NO. 13-2

TITLE:	Tuktoyaktuk Harbour Benthic Biological Monitoring Programme
PRINCIPAL INVESTIGATORS:	D.J. Thomas
AFFILIATION:	Seakem Oceanography Ltd.
FUNDING SOURCE:	NOGAP
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NOS.:	13 and 20

BRIEF PROJECT DESCRIPTION

A monitoring programme was conducted during 1986 and 1987 to assess the potential biological effects of chronic chemical contaminant inputs into Tuktoyaktuk Harbour on the benthic fishes Arctic flounder (Liopsetta glacialis) and starry flounder (Platichthys stellatus). Measurements were made of (1) polyaromatic and alkane hydrocarbons in flounder liver, bile and flesh; (2) mixed function oxidase enzyme activity in flounder liver; (3) PAH metabolites in bile; (4) mercury in flounder flesh; and (5) the incidence of idiopathic liver lesions. In addition, hydrocarbons were measured in the sediments of Tuktoyaktuk Harbour and the reference locations, and in the water column in Tuktoyaktuk Harbour.

The main findings of the study were:

(1) petroleum hydrocarbons (alkanes and PAH) were enriched in the sediments of Tuktoyaktuk Harbour relative to areas outside the harbour;

(2) dissolved alkane and aromatic hydrocarbon concentrations in the water of Tuktoyaktuk Harbour were at or near the detection limit;

(3) PAH metabolites were detected in the bile of all starry flounder and arctic flounder in this study;

(4) only one of the 116 fish examined in this study (0.9%) showed a neoplastic condition (liver cell adenoma);

(5) only three fish (2.6%) were affected by foci of cellular alteration; 7 fish (6%) showed the presence of nuclear pleomorphism. (Both conditions are considered to be pre-neoplastic);

(6) neoplastic and pre-neoplastic conditions were observed only in fish from Tuktoyaktuk Harbour. These conditions were not seen in the fish collected at the reference locations, nor were they seen in any of the starry flounder;

(7) the arctic flounder having neoplastic or pre-neoplastic conditions also had the highest concentrations of mercury in muscle tissue;

(8) of the 10 fish showing neoplastic or pre-neoplastic conditions, 8 (80%) were females;

(9) except for mercury and PAH in liver tissue, the contaminant tissue burden of fish showing neoplastic or pre-neoplastic conditions were not significantly different ($p < 0.05$) from those of reference area fish or fish not showing those conditions;

(10) MFO enzyme activity in fish showing neoplastic or pre-neoplastic conditions was significantly higher ($p < 0.05$) than that in fish at the reference area (Mason Bay) or in fish not showing those conditions; and

(11) there was a significant difference ($p < 0.05$) for values of the liver somatic index (liver weight/total fish weight) and gonadosomatic index (gonad weight/total fish weight) between fish captured in Tuktoyaktuk Harbour and those captured at the Mason Bay sites. For both indices, values obtained for Mason Bay (reference site) fish were higher than those obtained for fish collected at Tuktoyaktuk Harbour.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

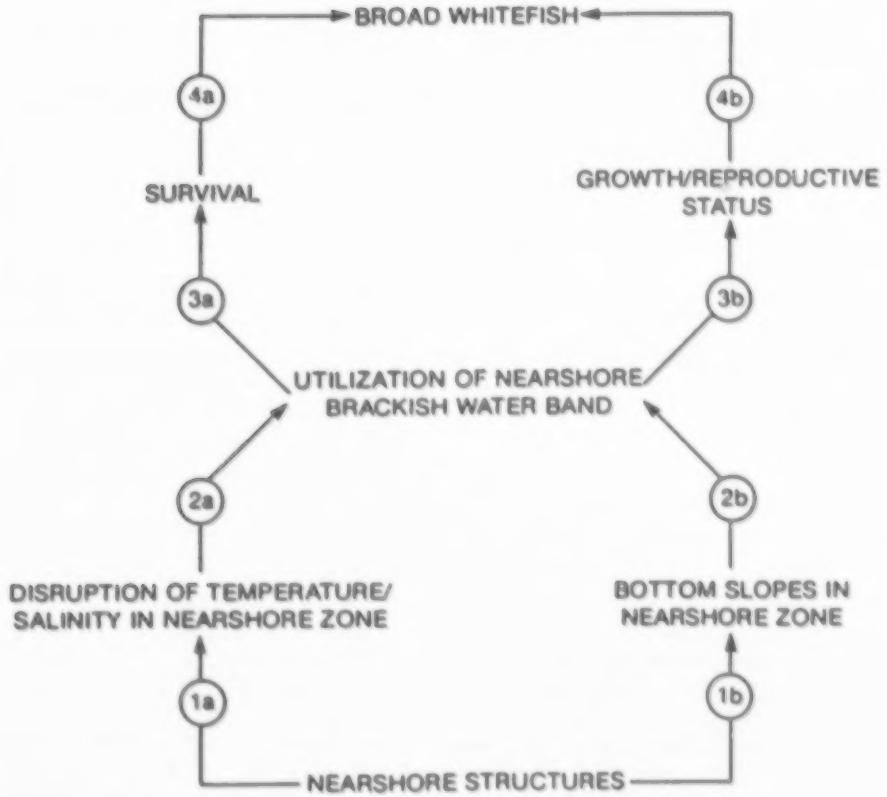
This study is of relevance to Hypothesis 13 and 20, in which a decrease in fish harvest is linked to increased body burdens of hydrocarbons in fish flesh. The study indicates that hydrocarbons are indeed accumulated by flounder in Tuktoyaktuk Harbour. It is unknown, however, whether the concentrations of hydrocarbons found in fish flesh in this study affect the native fisheries because the species studied are not harvested. The results of the study are of general value to those aspects of BEMP related to the accumulation of contaminants in the coastal Beaufort Sea, possible mobility of the contaminants within arctic marine food chains, and possible biological effects of contaminants on fish.

HYPOTHESIS NO. 14

Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish population.

FIGURE 14-1

POTENTIAL EFFECTS OF NEARSHORE STRUCTURES ON THE BROAD WHITEFISH POPULATIONS



BEMP IMPACT HYPOTHESIS NO. 14

LINKAGES

1a. Shoreline modifications will change temperature and salinity characteristics of the brackish water band along the Tuktoyaktuk Peninsula.

1b. Nearshore structures will change the slope of the sea bottom within the brackish water band along the Tuktoyaktuk Peninsula.

2a. Disruption of the brackish water band will result in decreased utilization of the nearshore zone by broad whitefish.

2b. Changes in nearshore sea bottom slope will alter utilization of nearshore waters by broad whitefish.

3a. The reduced time spent in the nearshore brackish zone will cause an increase in mortality of broad whitefish.

3b. Disruption of nearshore habitat will cause a decrease in feeding time and consequently a reduction in growth and fecundity.

4a. Increase in mortality of broad whitefish would lead to a decrease in the number of spawners, and subsequent reduction in the number of harvestable fish.

4b. Reduction in fecundity and reduced viability of eggs and young would result in fewer available fish for the harvest.

BEMP IMPACT HYPOTHESIS NO. 14

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 14

During the 1985 workshop, two new links were added to this hypothesis to include consideration of the effects of changes in the slope of the sea bottom due to nearshore structures (Link 1b) and causeway construction (Link 2b) on broad whitefish. While there is some evidence to suggest that bottom slope (as well as other factors such as food availability, water depth, turbidity and light) may influence the distribution of broad whitefish, the most likely factors determining their distribution were thought to be temperature and salinity. Studies of causeways in Prudhoe Bay indicate that nearshore structures could cause changes in temperature and salinity regimes that subsequently affect the distribution of broad whitefish in the southeastern Beaufort Sea. However, it is not known if such changes in distribution would have significant implications to broad whitefish populations or their harvest.

Since this workshop, a number of research programs have been completed by the Freshwater Institute (DFO) that lend further support to one or more of the linkages in this hypothesis. Specifically, these investigations have provided additional information on the seasonal movement patterns (Project Overview 14-1), habitat preferences (Project Overview 14-3), and individual stock attributes (Project Overview 14-4) of broad whitefish populations in the region.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 14-1

TITLE:	Spawning, migration, overwintering and dispersal of broad whitefish
PRINCIPAL INVESTIGATORS:	K. Chang-Kue
AFFILIATION:	Dept. of Fisheries and Oceans Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	14

BRIEF PROJECT DESCRIPTION

Research on the seasonal movements and migrations of broad whitefish in the Mackenzie River/Tuktoyaktuk Peninsula area was initiated in 1971 and has progressed through 3 study phases. The first of these was completed between 1971 and 1975, and involved tagging whitefish in the Mackenzie Delta with floy tags to monitor their general migration. The majority of whitefish in the lower Mackenzie were found to be in the 7-14 year age class (0-7 year old whitefish were conspicuous by their relative absence). Subsequent recapture of tagged fish

in the domestic fisheries indicated that extensive migrations of these spawning-age fish occurred each fall through the Delta to unknown spawning sites upstream. This study was followed by a 3-year investigation (1978-1981) to examine the seasonal movements of whitefish in several Tuktoyaktuk Peninsula creeks that drain into the Beaufort Sea. It was in these streams where the young-of-the-year (YOY) and 1-8 year age classes were prominent. Fish counting operations in two representative stream revealed a complex pattern of upstream and downstream migrations involving groups, by decreasing year class, of immature fish from ice break-up to freeze-up. While many of the upstream migrants return downstream to overwinter in shallow coastal waters after summer feeding in the freshwater lakes of the Peninsula, most of the YOY remain in the lakes for up to 4 years before joining the group of migrants that make the annual feeding forages into the lakes. Tagged immature and subadult whitefish were recovered in subsequent years as spawning migrants in the Mackenzie Delta.

To address many of the uncertainties regarding actual timing, movement patterns and destinations of migratory broad whitefish, the present study was initiated in 1982. Specifically, this study was designed to: (1) provide detailed information on the fall migration of broad whitefish; (2) identify major spawning grounds in Tuktoyaktuk Peninsula and Mackenzie estuary areas; and (3) identify overwintering habitats along the Mackenzie River and Delta. Whitefish were tagged with low frequency radio transmitters at pre-spawning aggregation sites near Fort Good Hope in 1982 and at Horseshoe Bend in the Mackenzie Delta in 1982, 1983 and 1984. Results of monitoring indicated that most of the fish tagged at Horseshoe Bend spawned at Point Separation in early November and then rapidly migrated downstream to overwintering sites in the outer west edge of the Delta, in the East Channel and in one coastal bay (Whitefish Bay).

From 1985 to 1987, the study focussed on examining the movements of downstream migrants in the Tuktoyaktuk Peninsula rivers. In 1985, whitefish (8-12 year olds) were radio tagged in Kukjuktuk Creek. Tracking of these individuals indicated that they migrated westward toward the Mackenzie Delta, following the nearshore along lagoons and harbours. The fish reached the delta by mid August, and were found in holding areas by mid September. By mid October, most of the fish were migrating upstream to spawn, which occurred in the first week of November. Two of the tagged fish (presumably the non-spawning segment of the group) did not display this spawning migration and migrated only as far as the East Channel and Whitefish Station.

In 1986 and 1987, 25 whitefish in Kittigazuit Creek, 10 whitefish in Canyanek Creek and 10 in Keneksek Creek were radio tagged to study the late summer and fall migration. The majority of these fish were immature (i.e., less than 8 years old). Tracking of these individuals indicated that the immature fish migrated downstream and proceeded to Whitefish Bay. By late October and November, the fish still resided within the inlet, supporting the hypothesis that immature coregonids migrate downstream to overwinter in coastal bays. Several of the larger fish made the typical spawning migration to the Mackenzie Delta. In September 1986, timer-activated tags were applied to 8 large whitefish at Horseshoe Bend to monitor the early spring activity of post-spawners. However,

these tags failed to activate.

In 1987, 19 whitefish were tagged in Whitefish Bay as well as 20 in Kittigazuit Creek, the main stream flowing into the bay. Tracking of these individuals confirmed previous results that immature fish remain in the bay to overwinter.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is most relevant to Hypothesis 14, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water along the Tuktoyaktuk Peninsula and reduce the broad whitefish population". The underlying assumption of this hypothesis is that broad whitefish use the nearshore freshwater zone found along the Tuktoyaktuk Peninsula as the migratory route between spawning or overwintering areas in the MacKenzie River or Estuary and the nursery and feeding areas in freshwater lakes on the peninsula. Interruption of this route by the diversion of coastal waters to offshore areas by long causeways could have population-wide effects on the broad whitefish that inhabit the region through decreased survival (Link 4a) or decreased growth and reproductive potential (Link 4b).

BEMP PROJECT OVERVIEW NO. 14-2

TITLE:	**Mackenzie Shelf Coregonid Young-of-the-Year Distribution Study**
PRINCIPAL INVESTIGATOR:	G.A. McKinnon
AFFILIATION:	Dept. of Fisheries and Oceans Freshwater Institute
FUNDING SOURCE:	DFO
EXPECTED COMPLETION DATE:	1990
RELEVANT BEMP HYPOTHESIS NO.:	14

BRIEF PROJECT DESCRIPTION

At present, there is insufficient information regarding habitat requirements, distribution and temporal movements of young-of-the-year (YOY) coregonids along the Beaufort Sea coast. This study is specifically designed to test the hypothesis that dispersal of YOY coregonids is controlled by the outflow of Mackenzie River water along the coast and that year class strength is a function of the extent of distribution of river water in any given year.

The abundance and distribution of YOY coregonids will be examined by systematic sampling using tows, purse seines and beach seines. Physical measurements including temperature, salinity, depth, turbidity and geographic

location of sampling will also be recorded.

This study was initiated in July and August 1987 with field trials to refine sampling methods and procedures. Limited systematic data were collected due to the experimental nature of the work. Sampling focussed on a small area bound by Tuft Point to the east, Hendrickson Island to the north and Kittygazuit to the west, but will be expanded in 1988 to encompass nearshore areas along Tuktoyaktuk Peninsula to the east and Mackenzie Bay to the west. Open water areas of Kugmallit Bay will be sampled as soon after Mackenzie River breakup as possible and will include the use of purse and beach seines, neuston nets and C.S.T.D. equipment. Inter-year variability in coregonid distribution within Kugmallit Bay and along the Tuk Peninsula is expected to be examined in 1989. A data report will be published annually, and a technical report is expected upon completion of the research.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is of direct relevance to Hypothesis No. 14, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish populations". The study will aid in evaluating Links 2a and 2b because it will provide basic information on the abundance and seasonal use of nearshore areas by YOY coregonids and oceanographic factors that may influence their distribution patterns along the Beaufort Sea coast.

BEMP PROJECT OVERVIEW NO. 14-3

TITLE:	Salinity Tolerance of Whitefish
PRINCIPAL INVESTIGATOR:	B. deMarch
AFFILIATION:	Dept. of Fisheries and Oceans, Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	14

BRIEF PROJECT DESCRIPTION

The overall objectives of this study were to: (1) provide background data to explain and predict juvenile and adult whitefish migration patterns in dispersal corridors in the nearshore Beaufort Sea in relation to salinity/temperature patterns; and (2) determine the effect of crude oil exposure on young broad whitefish acclimating to changes in salinity. However, the latter objective could not be met due to problems in producing a sufficient number of larvae from the established brood stock for testing.

BEMP IMPACT HYPOTHESIS NO. 14

The first phase of the study involved conducting laboratory experiments on wild juvenile fish (broad whitefish, lake whitefish and least cisco) collected from Freshwater Creek, near Tuktoyaktuk, to determine the tolerance of these fish to a range of salinity levels and rates of salinity change. Results of this work showed that C. nasus tolerated between 4 °/₀₀ and 20 °/₀₀ for more than 3 days at 14°C. However, mortality was observed within 3 days of exposure to salinities of 20-27 °/₀₀ and within 54 hours at salinities greater than 27 °/₀₀.

In 1986, broad whitefish eggs were collected from spawning aggregations in the lower MacKenzie River. Once the brood stock had been established, the larval fish and fry were exposed for 3-8 days to varying salinity and temperature. Three experiments were conducted with fish ranging in size from 12-18 mm, 15-19 mm and 27-68 mm to examine the effect of age on tolerance to changing salinities. Results of experiment 1 showed that both salinity and temperature were factors in the mortality of small juvenile coregonids (12-18 mm in size). At 5 and 10°C, mortality was observed within 5 days at all salinities tested between 12.5 and 25 °/₀₀, although this appeared to be delayed at water temperatures of 5°C. At 15°C, these fish tolerated salinities of 12.5 and 15 °/₀₀ for 5 days, but this was not observed at higher salinities. Slightly larger (15-19 mm) and older fish used in experiment 2 tolerated 10 and 12.5 °/₀₀ but not 15 °/₀₀ at water temperatures of 5, 10 and 15°C. In experiment 3, salinities greater than 16 °/₀₀ generally caused mortality of the larger (33-68 mm) fish within 5 days. Temperature did not appear to have a significant effect on the tolerance of these fish to varying salinities.

Results of this study were consistent with information available on the life history of Coregonus nasus. The experiments demonstrated that the smaller larval fish were not tolerant of even low saline water (12.5 °/₀₀) and that the combined effect of changing salinity and temperature was most evident with these younger fish. In their natural environment, small juvenile coregonids most likely remain well within the Mackenzie Delta or the East Channel, where freshwater conditions exist. The tolerance of C. nasus to changing salinities is related to their size, an adaption that is of obvious value to larger fish that are sometimes found farther from shore.

Results of this work will be published in Can. J. Zool. in early 1989.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project is most relevant to Hypothesis 14, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish population". Results of this study have shown that C. nasus is not more tolerant of saline conditions than other freshwater or migratory fish species and its distribution along the coast is determined largely by salinity.

BEMP IMPACT HYPOTHESIS NO. 14

BEMP PROJECT OVERVIEW NO. 14-4

TITLE:	Whitefish Stock Description
PRINCIPAL INVESTIGATOR:	J. Reist
AFFILIATION:	Dept. of Fisheries and Oceans, Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
RELEVANT BEMP HYPOTHESIS NO.:	14, 16 and 17

BRIEF PROJECT DESCRIPTION

As part of a NOGAP-funded program to assess critical freshwater habitat in the western Arctic, this study was initiated in 1983 to assess the presence and geographical limits of genetic stocks of broad whitefish, Coregonus nasus, in the lower Mackenzie River. Specifically, this study is aimed at determining the discreteness and number of broad whitefish stocks in the Mackenzie River drainage through morphometric, meristic and electrophoretic techniques. Samples of whitefish have been collected from the Mackenzie Delta and at several locations upstream. These specimens are being examined to determine the usefulness of specific characteristics as stock identifiers.

In 1986, approximately 1780 fish collected from the study area and from Alaska (for comparative purposes) during the 1985 field program were processed. This included taking 20 measurements, 9 meristic counts and 4 measurements of biological parameters, examination for scarring and external parasites and extraction of muscle, heart and liver tissue for biochemical analysis. Scale-aging of all broad and lake whitefish collected in 1983, 1984 and 1985 has been completed, and analysis of all other species is being conducted.

To date, the results of this study have indicated that broad whitefish in the lower Mackenzie River are structured into distinct genetic stocks on the basis of one or more of the following:

(1) within a year by spawning aggregations associated with major features of the lower Mackenzie Basin (e.g., tributaries such as Peel and Arctic Red rivers);

(2) possibly between successive years within spawning areas;

(3) likely as migratory groups moving to and, perhaps, from spawning areas;

(4) as juveniles in rearing areas such as the lakes of Tuktoyaktuk Peninsula; and

(5) as life history types (e.g., an anadromous form exhibiting typical migratory behaviour to/from spawning sites; a lacustrine form spending most life history within larger lake systems; and a riverine

but non-anadromous form).

Data analysis, publication of results and synthesis of findings with other NOGAP B.3 subprojects will be completed over the next two years. Funding for additional field work is being pursued.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is of relevance to all hypotheses concerning broad whitefish because it will provide data that will aid in assessment of the possible effects of hydrocarbon development on this species. If separate populations of broad whitefish exist in the region, they may be more susceptible to some development activities, particularly if such populations remain as relatively discrete units while in the Beaufort Sea. Genetic structuring of broad whitefish populations within the region also has profound implications for fisheries management and planning for mitigation of environmental impacts.

BEMP PROJECT OVERVIEW NO. 14-5

TITLE:	Prudhoe Bay Waterflood Project, Fish Distribution Surveys
PRINCIPAL INVESTIGATORS:	L.L. Moulton, R.G. Fechhelm and B.J. Gallaway
AFFILIATION:	Environmental Science & Engineering and LGL Ecological Research Associates
FUNDING SOURCE:	U.S. Army Corps of Engineering, Alaska District
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	14 and 15

BRIEF PROJECT DESCRIPTION

The following is the abstract that appears in the Prudhoe Bay Waterflood Project Comprehensive Marine Report, which summarizes the results of fish distribution studies undertaken as part of the Waterflood Environmental Monitoring Program. From 1981 to 1984, a number of studies were conducted on the distribution and movements of fish around the West Dock causeway, near Prudhoe Bay (Griffiths and Gallaway 1982; Critchlow 1983; Biosonics 1984; Moulton et al. 1986). The specific objectives of the studies changed each year, but the two major program objectives were to evaluate the effects of the causeway on fish movements and fish use of the region and habitats in the vicinity of West Dock.

These studies focussed on four anadromous species: least cisco (Coregonus sardinella), Arctic cisco (C. autumnalis), broad whitefish (C. nasus), and Dolly Varden char (Salvelinus malma). Least cisco in the region originate from the

Colville River. Young (ages 1 to 5) arctic cisco found near West Dock in the summer had overwintered in either the Sagavanirktok or Colville rivers, although all fish of this species found in Alaskan water are thought to originate from spawning in the Mackenzie River in Canada. Since there is little overwintering in the Sagavanirktok River for Arctic cisco, most of the larger fish (ages 6 to 8) caught during the summer come from the Colville River overwintering areas. Broad whitefish enter the vicinity of West Dock from the Colville and Sagavanirktok rivers, both of which have reproducing populations. Dolly Varden char in the study area are a mix of stocks from various rivers across the coast, but are probably dominated by char from the Sagavanirktok River, which supports the largest population and is the closest char river to the study area.

All four species utilize the estuarine water of the nearshore Beaufort Sea for feeding during the summer. Broad whitefish is the species least tolerant of marine conditions (cold, high salinity water). They remain near the river deltas for most of the summer. Least cisco are more tolerant of marine water than broad whitefish, and are followed by Arctic cisco and Dolly Varden char in order of increasing tolerance of low temperatures and high salinity. The four species utilize the coastal area from late June or early July until early September, with a few individuals of each remaining in the coastal regions into mid-September. They are present near the West Dock causeway from early to mid-July until mid-August to late August.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This research provides information directly relevant to Hypothesis No. 14, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish populations". These studies aid in evaluating Links 2a and 2b because they provide basic information on the abundance and seasonal use of the nearshore areas by coregonids and oceanographic factors that influence their distribution patterns along the coast. During the summer feeding period, broad whitefish tend to be found in warm, low salinity water and in close proximity to the Kuparuk and Sagavanirktok river deltas. Larger (cohort 4) fish appear to be more tolerant of colder, higher saline water than the smaller broad whitefish, but also tend to remain in estuarine waters to feed. This trend is consistent with numerous other studies conducted along the Alaskan and Canadian Beaufort Sea coast. In midsummer, the West Dock causeway blocks the warm, low salinity water plumes of the Sagavanirktok and Kuparuk rivers, which under east winds are replaced by upwelling of cold marine water. Fish use of West Dock lagoon as feeding habitat has likely been reduced due to the presence of this causeway.

This research is also relevant to Hypothesis No. 15, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water and will reduce the Alaskan population of Arctic cisco". These studies have defined use of the nearshore zone as feeding habitat and a migration corridor for Arctic cisco, which originate from a spawning stock in the Mackenzie

River. This population could be affected by both the Prudhoe Bay causeway and all nearshore structures built between the Mackenzie Delta and the westward limit of the arctic cisco distribution in the Alaskan Beaufort Sea.

In addition, this research also provides information on the distribution and use of habitat of other fish species, which occur along the coast. These data will provide the basis for evaluation of the need for future monitoring programs related to hydrocarbon development activities in the southeastern Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 14-6

TITLE:	**Prudhoe Bay Waterflood Project, Fish Feeding Studies**
PRINCIPAL INVESTIGATOR:	R.G. Fechhelm, W.B. Griffiths, and D.R. Schmidt
AFFILIATION:	LGL Ecological Research Associates
FUNDING SOURCE:	U.S. Army Corps of Engineering, Alaska District
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	14

BRIEF PROJECT DESCRIPTION

The following is the abstract that appears in the Prudhoe Bay Waterflood Comprehensive Marine Report, which summaries the results a fish feeding study conducted during the 1984 Waterflood Environmental Monitoring Program (Moulton et al. 1986). This study involved examining the stomach contents of four anadromous fish species (Arctic cisco, least cisco, broad whitefish, and char) and two marine species (Arctic cod and fourhorn sculpin) to determine trophic relationships in the nearshore coastal environment during summer. Data were pooled to compare feeding habits in Prudhoe Bay versus the Gwydyr Bay lagoon system during early, mid and late summer.

The principal prey of the four anadromous and two marine species of fish during the 1984 Waterflood study consisted of two mysid species, M. litoralis and M. relicta, amphipods, isopods, fish, copepods, chironomid larvae, and to a lesser extent polychaetes, priapulids and insect larvae. Arctic cisco fed primarily on mysids and amphipods throughout the summer. Arctic cisco appeared to select for M. litoralis, which confirms trends observed in the 1985 and 1986 Endicott studies. Least cisco fed on mysids and amphipods, and to a lesser extent, fish. There was strong evidence of dietary overlap between least cisco and Arctic cisco; however, results may have been biased by the lumping of individual amphipod species into one prey category. Arctic cod fed primarily on mysids and amphipods, and their diet overlapped with that of Arctic cisco. The seasonal effect of such trophic competition would depend on the timing, and

extent of the onshore movement of Arctic cod during the summer. Fourhorn sculpin fed primarily on amphipods, isopods, and fish and appear to select against mysids. The diet of fourhorn sculpin overlapped with that of char, but the results are probably an artifact of field sampling methodology. Much of the overlap was due to the presence of fish, and fourhorn sculpin feed voraciously on small fish when trapped in fyke nets. Char diet varied throughout the season and between locations with fish feeding on every prey group except copepods and "other taxa". Broad whitefish fed primarily on amphipods and chironomids. Exploitation of the freshwater chironomids is consistent with broad whitefish distribution in that they remain in close proximity to river mouths. Despite a distinct differential in fish size based upon the two major habitats - Prudhoe Bay and Gwydyr Bay - diet overlapped substantially. For the season, there was significant dietary overlap within all six species based upon two habitats indicating a continuity in feeding habitat throughout the overall study area with no delineation associated with the presence of West Dock. The biomass levels of "total prey" in Gwydyr Bay and in Prudhoe Bay and Gwydyr Bay combined was significantly associated with biomass levels in the stomachs of Arctic cisco greater than 160 mm collected in Gwydyr Bay. Data suggests that these large Arctic cisco may modify their food intake relative to environmental levels. For all the four anadromous fish species, increasing holding time in fyke nets from 0-6 h to 0-24 h substantially increases the percentage of observed empty stomachs.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

These studies are of direct relevance to Hypothesis No. 14, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish populations". This research provides information on feeding areas of broad whitefish and the importance of river deltas as feeding habitat. Broad whitefish tend to be confined to warm low salinity water of river deltas. Adults migrate away from the deltas in early summer before the midsummer transition to feeding areas. Young are sometimes abundant near the mouths of rivers in late summer in low to moderate salinity waters feeding on copepods.

BEMP IMPACT HYPOTHESIS NO. 14

BEMP PROJECT OVERVIEW NO. 14-7

TITLE:	Prudhoe Bay Waterflood Project, Fish Prey Surveys
PRINCIPAL INVESTIGATOR:	R.G. Fechhelm, D.R. Schmidt, and W.B. Griffiths
AFFILIATION:	LGL Ecological Research Associates
FUNDING SOURCE:	U.S. Army Corps of Engineering, Alaska District
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	14 and of general interest

BRIEF PROJECT DESCRIPTION

The following is the abstract that appears in the Prudhoe Bay Waterflood Comprehensive Marine Report, which summaries the results of a fish prey survey conducted as part of the Waterflood Monitoring Program (Moulton et al. 1986). The objectives of this survey were to: (1) determine the relationships between the distribution of dominant anadromous fish species in the Prudhoe Bay area and the distribution of their prey items; (2) identify physical factors that may control the distribution of prey; and (3) determine how the presence of the West Dock causeway may affect the trophic character of the Prudhoe Bay area. The findings of other investigations conducted in the region are also integrated in this review.

Drop net surveys were conducted in the vicinity of Prudhoe Bay, Alaska during the summer 1984. The most consistent feature of the survey was that biomass levels of Mysis litoralis, M. relicta, amphipods, isopods, and copepods generally tended to be highest in the vicinity of the West Dock causeway, particularly at its tip. Data suggest that the West Dock causeway accumulates large concentrations of prey by: (1) providing sheltered areas in which prey tend to concentrate, (2) intercepting longshore flow and entrained organisms, and (3) developing an area that is subject to strong marine water intrusions. Whether this enhanced onshore recruitment of marine prey (beneficial to fish) is offset by the marine conditions that accompany it (avoided by fish) remains unclear. Total prey biomass generally increased throughout the course of the summer. This is consistent with the marine nature of the taxa and the progressively more marine conditions during the season. There was no evidence of a consistent association between the distribution of anadromous fish and the distribution of their prey.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

These studies are of direct relevance to Hypothesis No. 14, which states that "Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish populations". The abundant levels of prey in the

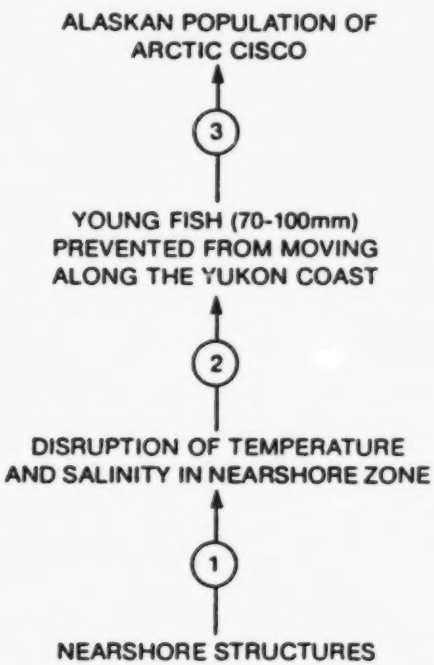
nearshore zone appears to be the primary reason that broad whitefish (and other anadromous fish species) migrate from their freshwater environment and disperse through coastal waters. The distribution and localized abundance of prey may, therefore, be an important factor influencing the distribution of this species and in defining habitat preference and trophic usefulness. Results of this research indicated that, although there was considerable heterogeneity among sampling sites, biomass levels for most of the major prey taxa generally increased throughout the summer as marine waters mixed with nearshore water masses. High concentrations of all of the major taxa were consistently found at the tip of West Dock. Although broad whitefish tend to avoid cold, high salinity conditions - the same conditions that facilitate the onshore movement of principal prey items - this species partially compensates by relying heavily on freshwater food sources such as chironomids.

HYPOTHESIS NO. 15

Nearshore structures will disrupt the nearshore band of warmer brackish water and will reduce the Alaskan population of arctic cisco.

FIGURE 15-1

POTENTIAL EFFECTS OF NEARSHORE STRUCTURES ON THE ALASKAN POPULATION OF ARCTIC CISCO


ALASKAN POPULATION OF ARCTIC CISCO
3
YOUNG FISH (70-100mm) PREVENTED FROM MOVING ALONG THE YUKON COAST
2
DISRUPTION OF TEMPERATURE AND SALINITY IN NEARSHORE ZONE
1
NEARSHORE STRUCTURES

LINKAGES

1. Shoreline modification will change temperature and salinity patterns of the brackish water band along the Yukon Coast during summer.

2. Disruption of the brackish water band will result in decreased movement of young Arctic cisco from the Mackenzie Delta to the Alaskan Beaufort Sea coast.

3. Decreased movement of Arctic cisco will cause directly proportional decreases in the Alaskan population of Arctic cisco.

BEMP IMPACT HYPOTHESIS NO. 15

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 15

During previous workshops, it was concluded that the links in Hypothesis No. 15 could not be proven or disproven on the basis of existing information and there was no evidence for rejection of the overall hypothesis. However, recent investigations conducted near the Prudhoe Bay causeway have provided evidence in support of this hypothesis (Project Overview 15-3). Studies conducted along the Yukon North Slope and in the Alaskan Beaufort Sea have provided information to verify the underlying assumption that Alaskan arctic cisco spawn in the Mackenzie River and that juveniles then migrate along the Yukon coast to spend a number of years in Alaskan waters before mature or nearly mature fish return to the Mackenzie River to spawn (Project Overviews 15-1 and 15-2).

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 15-1

TITLE:	**Yukon North Slope Fish Habitat Assessment**
PRINCIPAL INVESTIGATOR:	W. Bond
AFFILIATION:	Dept. of Fisheries and Oceans, Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	15, and of general interest

BRIEF PROJECT DESCRIPTION

As part of a NOGAP-funded program to assess critical estuarine and marine habitats of the Canadian Arctic continental shelf (Program B.2), a two-year study was initiated to examine the significance of Yukon nearshore habitats to marine and anadromous fish species. The primary objectives of this study were to:

1. enhance the existing data base pertaining to the life history of the marine and anadromous fishes utilizing nearshore habitats along the Yukon coast (species composition and distribution, age and growth, sex and maturity, food habitats);

2. describe the alongshore migratory patterns of anadromous fish during the open-water period;

3. identify specific areas within Phillips Bay that may be of importance to marine and anadromous fishes as feeding, spawning or nursery habitat; and

BEMP IMPACT HYPOTHESIS NO. 15

4. characterize inshore habitats (to the 5 m isobath) in terms of temperature and salinity, and relate these variables to fish distribution and movement patterns.

Gillnets, trapnets and seines were used to sample marine and anadromous fish populations between Kay Point and Stokes Point. Sampling was conducted during the open-water season, and the extent of anadromous fish movements were evaluated through the use of conventional (Floy) tags.

During the first field season (1985), fish populations in the vicinity of Phillips Bay were sampled using variable mesh gillnets and small mesh seines. These nets were employed on a regular weekly basis from 29 June to 21 August. Seven anadromous species accounted for 75% of the total catch, of which Arctic cisco (Coregonus autumnalis) was the most abundant (77%). The only marine or brackish water species captured in significant numbers were fourhorn sculpin (Myoxocephalus quadricornis) and Arctic flounder (Liopsetta glacialis), which accounted for 85% and 14% of this group, respectively. The results of this work are presented in a Canadian Data Report of Fisheries and Aquatic Sciences.

The 1986 sampling program focused on the use of trapnets to monitor the daily movements of fish. Sampling was initiated on 23 June and was completed by 08 September. A single codend trap was established on the inside of Niakolik Point, where it fished almost continuously over the sample period. Two other codend traps were set on the seaward side of the point. These traps were checked four times a day, at which time the fish were identified, counted and measured. Three sites along the 5 m isobath were sampled using bottom and surface paired gillnets with variable mesh sizes. A total of 23 sets were made over the summer at these sites. In addition, six sites were sampled on a regular basis using small mesh seines. A number of least cisco and Arctic char were marked by fin-clipping and about 2800 Arctic cisco were tagged with Floy tags to determine whether the fish were re-entering the traps and to examine their subsequent movements. Water temperature and salinity were determined daily at each trapnet site and with each fish collection at seine and gillnet sites.

A total of 142,797 fish were captured in trapnets during the 1986 field survey, of which 59.2% were anadromous and 40.7% were marine. Freshwater species represented only 0.1% of the total catch. Among the seven anadromous species captured, Arctic cisco was the most abundant (62.7% of the total catch). Catch per unit effort and mark-recapture data suggest that there was an early westward migration of large Arctic cisco through Phillips Bay and a late summer return to the Mackenzie Delta. A large migration of young-of-the-year Arctic cisco arrived in the bay during mid July, with numbers peaking in early to mid August and continuing into September.

A final report on the results and conclusions of this two-year study is presently being prepared for publication in 1989.

BEMP IMPACT HYPOTHESIS NO. 15

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is particularly relevant to Hypothesis No. 15, which states that "Nearshore structures will disrupt the nearshore band of warmer brackish water and will reduce the Alaskan populations of Arctic cisco". It will define use of the nearshore zone as a migration corridor for Arctic cisco and other fish species. The results of this program lend support to the underlying assumption of Hypothesis No. 15 that "Alaskan Arctic cisco" spawn in the Mackenzie River and then juveniles migrate along the Yukon coast to spend a number of years in Alaskan waters before mature or nearly mature fish return to the MacKenzie River to spawn.

BEMP PROJECT OVERVIEW NO. 15-2

TITLE:	**Wind-aided Recruitment of Canadian Arctic Cisco into Alaskan waters**
PRINCIPAL INVESTIGATORS:	R.G. Fechhlem and D.B. Fissel
AFFILIATION:	LGL Ecological Research Associates and Arctic Sciences Ltd.
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	15

BRIEF PROJECT DESCRIPTION

Arctic cisco (Coregonus autumnalis) is one of the most abundant anadromous fish species in coastal waters of the central Alaskan Beaufort Sea. During October and November of each year, considerable numbers of these fish are taken by the Colville River gillnet fishery. Because of the abundance of arctic cisco in Alaskan waters, it was initially believed that they spawned in some of the larger river systems of the Alaskan North Slope. However, recently, there has been increasing evidence that young-of-the-year are transported from the Mackenzie estuary into Alaskan waters during the ice-free season by prevailing longshore currents, where they reside in or near freshwater drainages until they become sexually mature. At this time, it is believed these fish then return to the Mackenzie River to spawn.

This study was initiated to further investigate this hypothesis and the oceanographic and meteorological factors that may control the recruitment of young-of-the year arctic cisco into Alaskan waters. The effect of wind-driven currents on annual recruitment was investigated by comparing summer wind patterns with commercial catches of arctic cisco at the Colville River for the period 1967-1985. To account for the 5-year difference in recruitment of age 0 fish into Alaskan waters and harvest of these fish in the commercial fishery, the wind time series was shifted forward 5 years. After adjusting for this differential in the two time series, it was found that there was a significant correlation

between yearly catch-per-unit effort and the percent of easterly winds. The greater the prevalence of easterly winds (westerly currents), the greater the recruitment of arctic cisco, which is manifested 5 years later as an increase in the Alaskan commercial fishery. The only exceptions to this were in years of severe ice conditions, where the outflow of the Mackenzie River was confined to areas immediately adjacent to the delta rather than being dispersed over a larger area of the Beaufort Sea. Presumably, this limited the recruitment of arctic cisco into Alaskan waters. It was speculated that unusually low overwater wind fetch during these years could have also caused the low catch-per-unit effort five years later.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is particularly relevant to Hypothesis No. 15. Results of this program provide evidence for the underlying assumption of this hypothesis that Alaskan arctic cisco spawn in the Mackenzie River and then juveniles migrate along the Yukon coast to spend a number of years in Alaskan waters before mature or nearly mature fish return to the Mackenzie River to spawn. Although the proportion of newly emerged fish that disperse westward into Alaskan waters is not presently known, the integrity of the Mackenzie River stocks could depend largely on the success of the Alaskan migrants. Recruitment projections based on wind-aided dispersal could be used as a baseline to measure the impact of petroleum development along the arctic coast.

In addition, this study is expected to provide basic descriptive information on other fish species that occur along the Yukon coast. These data will provide the basis for evaluation of the need for future monitoring programs related to hydrocarbon development activities in this part of the southeast Beaufort Sea.

BEMP IMPACT HYPOTHESIS NO. 15

BEMP PROJECT OVERVIEW NO. 15-3

TITLE:	**Prudhoe Bay Waterflood Project, Fish Tagging Studies**
PRINCIPAL INVESTIGATOR:	R.G. Fechhelm
AFFILIATION:	LGL Ecological Research Associates
FUNDING SOURCE:	U.S. Army Corps of Engineering, Alaska District
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	15 and of general interest

BRIEF PROJECT DESCRIPTION

The following is the abstract that appears in the Prudhoe Bay Waterflood Project Comprehensive Marine Report, which summarizes the results of fish tagging surveys conducted in conjunction with the 1981-1984 Waterflood, 1983-1984 Lisburne, and 1982 Endicott fish monitoring surveys. Anadromous fish were marked and tagged to document their regional and local movement patterns and to aid in the assessment of fyke net catch data. Efforts were directed at four key fish species: Arctic cisco (Coregonus autumnalis), least cisco (C. sardinella), broad whitefish (C. nasus), and char (Salvelinus alpinus).

The mark/recapture studies provided valuable information for assessing West Dock causeway's potential impact on the longshore movement of Arctic anadromous fish and expanded general knowledge of life history and migratory patterns. Some of the more noteworthy contributions of these studies included the following:

(1) supported the hypothesis that Arctic cisco found in the central Alaskan Beaufort Sea are temporary residents that migrate westward from Canada's Mackenzie River system and that they eventually return to that drainage to spawn;

(2) provided quantitative evidence that both large and small least cisco migrating eastward from the Colville River may be blocked from moving into Prudhoe Bay by hydrographic conditions in the vicinity of (and partially caused by) the West Dock causeway;

(3) showed that large specimens of Arctic cisco, least cisco and char are capable of travelling in excess of 10 km per day and as much as 24 km per day, a feature that could make causeways less of a barrier to longshore migration;

(4) provided evidence that the West Dock causeway does not prevent large Arctic and least cisco from returning to the Colville River;

(5) indicated that small Arctic cisco from the Sagavanirktok River dispersed as far west as Oliktok Point in 1983; and

(6) supported catch data for the 1984 season in suggesting that small Arctic cisco from the Sagavanirktok River delta underwent limited westward dispersal to the point that they rarely moved into northwest Prudhoe Bay.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

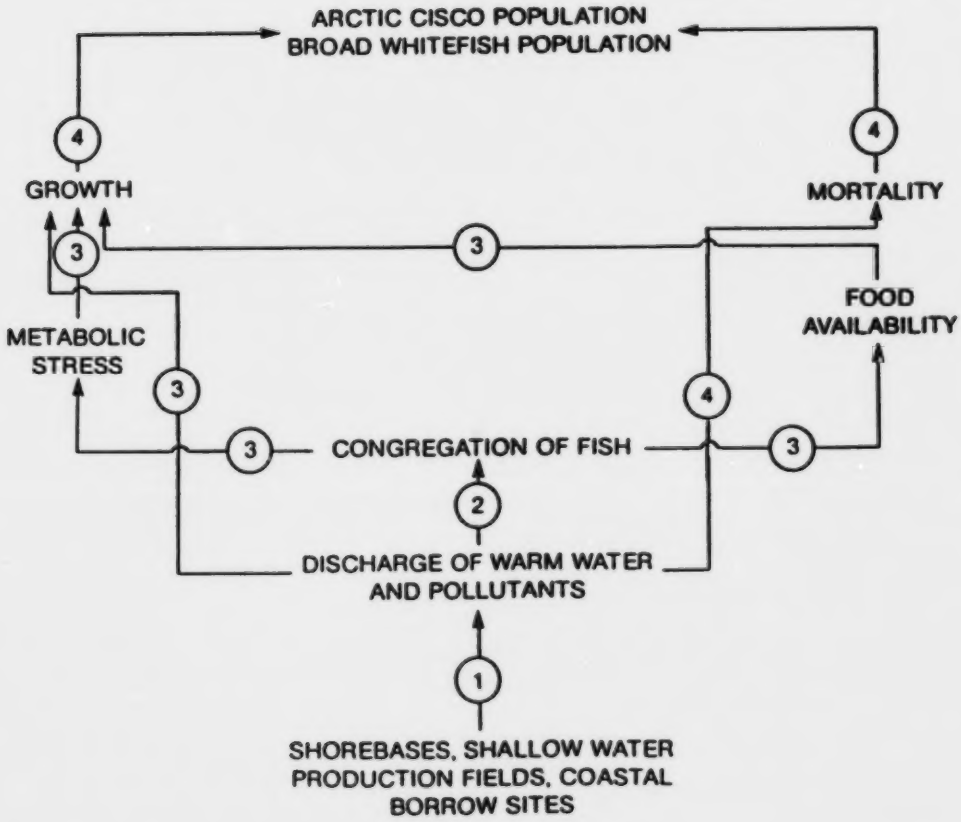
This research provides information directly relevant to Hypothesis No. 15. Results of these studies provide support to the underlying assumption that Arctic cisco found in the central Alaskan Beaufort Sea originate from the Mackenzie River and return there to spawn. Young (age 0) Arctic cisco migrate from the Mackenzie River to Alaskan waters between mid-August and mid September. Some delay at West Dock was suggested by the data collected during these studies, but the vast majority of the fish apparently move readily around the causeway and continue westward, either along the outer edge of the barrier islands or following the shoreline in Gwydyr Bay. Because migration of the young Arctic cisco typically continues through freeze up, any delay of movement may decrease recruitment into the Colville River. The potential for this decrease is largely dependent on how long fish continue to move westward under the ice after freeze up.

HYPOTHESIS NO.16

The construction of shorebases and development of shallow-water production fields will result in a decrease in the populations of arctic cisco and broad whitefish.

FIGURE 16-1

POTENTIAL EFFECTS OF DISCHARGES FROM PRODUCTION FIELDS AND OTHER FACILITIES ON ARCTIC CISCO AND BROAD WHITEFISH POPULATIONS



BEMP IMPACT HYPOTHESIS NO. 16

LINKAGES

1. Warm water effluents and production water will be discharged into the freshwater area of the outer Mackenzie Delta.

2. Fish will be attracted to thermal plumes.

3. Contaminants in produced water in areas where fish are congregated will result in increased stress, reduced food availability and decreased fish growth.

4. Direct mortality due to effluents and decreased growth will reduce Arctic cisco and broad whitefish populations.

BEMP IMPACT HYPOTHESIS NO. 16

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 16

As a result of a potential change in the development scenario involving the possible siting of a production facility (i.e., ARGO) in an area where the water depth is less than 5 m, Hypothesis No. 16 was re-evaluated during the 1985 workshop. Although participants concluded that the hypothesis was valid, significant impacts of production waste discharges from this field were considered extremely unlikely due to the small volumes of effluent expected. It was agreed that the hypothesis and possible research/monitoring needs should be re-evaluated in the future if anticipated volumes of produced water increase substantially from present estimates.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

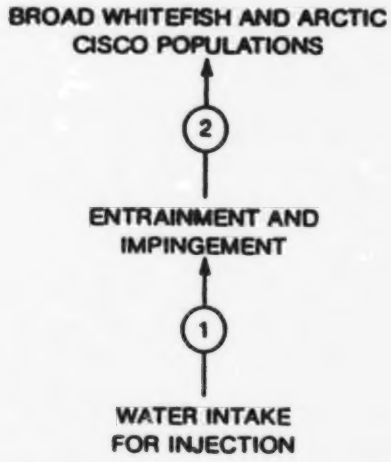
There have been no new research programs initiated since the 1985 workshop that are relevant to this impact hypothesis.

HYPOTHESIS NO. 17

Water intakes will reduce populations of broad whitefish and arctic cisco.

FIGURE 17-1

POTENTIAL EFFECTS OF WATER INTAKES ON BROAD WHITEFISH AND ARCTIC CISCO POPULATIONS



LINKAGES

1. The intake of water for reservoir injection will cause entrainment and impingement of juvenile broad whitefish and Arctic cisco.

2. The mortality associated with entrainment and impingement will reduce broad whitefish and Arctic cisco populations.

BEMP IMPACT HYPOTHESIS NO. 17

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 17

During previous workshops (1984, 1985), this hypothesis was considered extremely unlikely because the waterflood requirements in Canadian nearshore fields were expected to be small compared to those in the Alaskan fields. Nevertheless, it was recommended that the U.S. monitoring program results be reviewed to determine if this hypothesis should be re-evaluated at some future date.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 18

Air emissions resulting from the operation of aircraft, marine vessels, drill rigs, offshore platforms and shorebases will adversely affect air quality.

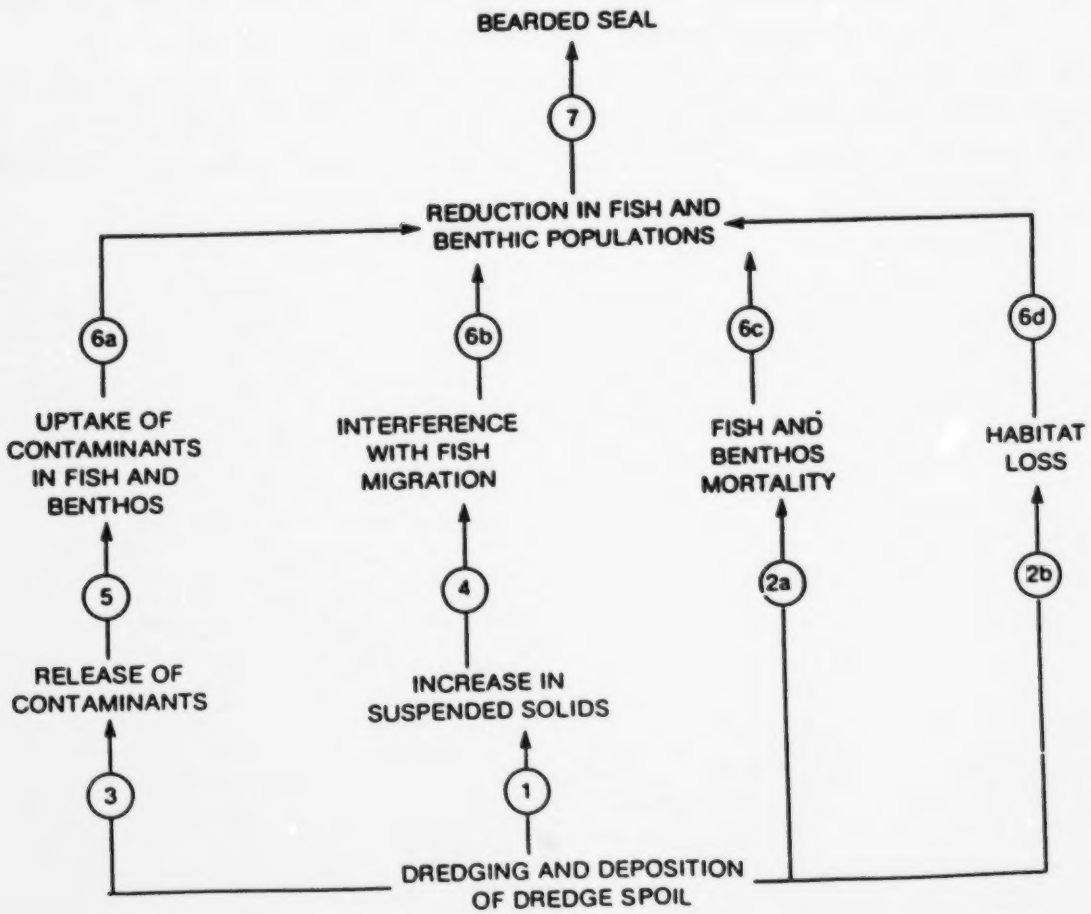
Given the anticipated quantities of air emissions associated with offshore hydrocarbon development in the Beaufort region, it was concluded that Hypothesis No. 18 was unlikely. This hypothesis has not been re-examined since the first BEMP workshop.

HYPOTHESIS NO. 19

Dredging and deposition of spoils will reduce the bearded seal populations.

FIGURE 19-1

POTENTIAL EFFECTS OF DREDGING AND DEPOSITION OF SPOILS ON THE BEARDED SEAL POPULATION



BEMP IMPACT HYPOTHESIS NO. 19

LINKAGES

1. Dredging and deposition of dredge spoils will increase concentrations of suspended solids in the water column.

2. Removal of seafloor material and its deposition in other areas will result in mortality of benthic invertebrates and fish and habitat loss.

3. Dredging will release contaminants from the sediments.

4. Increased suspended solids will interfere with fish migration.

5. Contaminants released during dredging will be taken up by fish and benthos.

6. Habitat loss, mortality, interference with migratory routes and uptake of contaminants will reduce fish and benthic invertebrate populations.

7. Reduced populations of prey (fish and benthos) will reduce the number of bearded seals.

BEMP IMPACT HYPOTHESIS NO. 19

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 19

The validity of Hypothesis No. 19 was evaluated during the 1985 workshop. On the basis of worldwide experience regarding the effects of dredging operations and the anticipated intensity and locations of dredging in the Beaufort Sea, this hypothesis was considered unlikely and did not justify testing. However, it was stated that bioaccumulation of some contaminants could occur in the livers of individual bearded seals if they fed in areas of active dredging for extended periods of time. It was recommended that heavy metal concentrations in bearded seal livers be measured on an opportunistic basis because of the link to human health.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

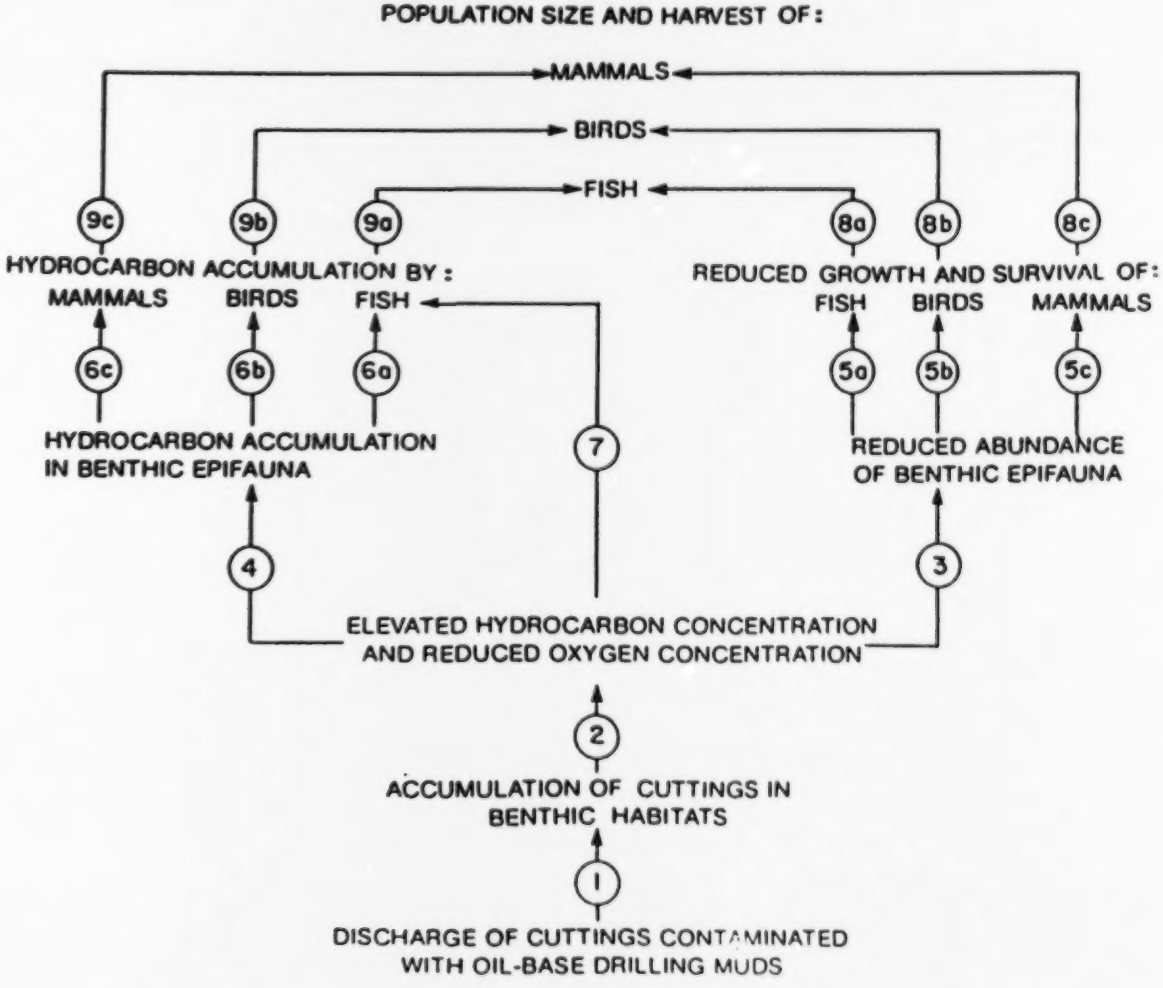
There have been no new research programs initiated in the last two years that are relevant to this impact hypothesis.

HYPOTHESIS NO. 20

The discharge of drill cuttings contaminated with oil-based drilling muds during hydrocarbon exploration or production will reduce populations of fish, birds or mammals or will decrease the harvest of these resources due to hydrocarbon accumulation in tissues.

FIGURE 20-1

EFFECTS OF CUTTINGS CONTAMINATED WITH OIL-BASE DRILLING MUDS ON THE POPULATIONS AND HARVEST OF FISH, BIRDS AND MARINE MAMMALS



BEMP IMPACT HYPOTHESIS NO. 20

LINKAGES

1. Cuttings contaminated with oil-base drilling muds and discharged during exploration and development drilling will rapidly settle to the seafloor, and resist subsequent widespread dispersion due to the cohesiveness of mud-cuttings mixtures.

2. In areas of cuttings accumulation, elevated hydrocarbon concentrations and reduced oxygen levels will occur during the slow degradation of oil-base muds.

3. The abundance of benthic fauna will be reduced in areas of mud-cuttings accumulation due to smothering, oxygen depletion and toxicity of petroleum hydrocarbons in drilling muds or the products resulting from their degradation.

4. Benthic fauna in habitats containing mud-cuttings mixtures will accumulate petroleum hydrocarbons.

5a. Decreased abundance of benthic fauna will affect the growth and survival of marine and anadromous fish.

5b. Decreased abundance of benthic fauna will affect the growth and survival of birds that feed on benthic prey organisms.

5c. Decreased abundance of benthic fauna will affect the growth and survival of marine mammals that feed on benthic prey organisms.

6a. Marine and anadromous fish will accumulate petroleum hydrocarbons from ingestion of contaminated prey.

6b. Birds will accumulate petroleum hydrocarbons from ingestion of contaminated prey.

6c. Marine mammals will accumulate petroleum hydrocarbons from ingestion of contaminated prey.

7. Marine and anadromous fish remaining in areas containing oil-contaminated cuttings will directly accumulate petroleum hydrocarbons.

8a. The size of marine and anadromous fish populations will be reduced due to local effects of reduced prey availability on growth and survival.

8c. The size of marine mammal populations will be reduced due to local effects of reduced prey availability on growth and survival.

9a. The harvest of fish will be reduced due to the presence of petroleum hydrocarbons in tissues or the perception that fish are of lower quality.

9b. The harvest of birds will be reduced due to the presence of petroleum hydrocarbons in tissues or the perception that birds are of lower quality.

9c. The harvest of marine mammals will be reduced due to the presence of petroleum hydrocarbons in tissues or the perception that marine mammals are of lower quality.

BEMP IMPACT HYPOTHESIS NO. 20

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 20

This hypothesis was re-evaluated during the 1986 workshop. It was concluded that discharge of oil-contaminated cuttings could affect the local abundance of fish, birds and mammals in shallow nearshore areas due to loss of benthic habitat, but was not a significant concern in offshore areas because of the scale of possible industrial activities. Bioaccumulation and biomagnification of hydrocarbons adhering to the drill cuttings was considered highly unlikely and would not justify testing through a monitoring program. The workshop participants recommended five areas of research and monitoring related to the use of oil-based drilling muds. These were: (1) determination of the fate of discharged oil-contaminated cuttings; (2) establishment of a hydrocarbon baseline data base; (3) identification of critical nearshore habitats for fish, birds and mammals; (4) evaluation of the potential for down-hole generation of polyaromatic hydrocarbons; and (5) examination of the oxygen demand of oiled cuttings in this region.

In response to these recommendations, a number of research and monitoring programs related to use of oil-based drilling muds in the Beaufort Sea were initiated, some of which have now been completed. Results of these studies provide information on the fate of oiled cuttings at two specific locations in the Beaufort Sea (Project Overview 20-1), the influence of river-borne hydrocarbons on fish quality (Project Overview 20-5 and 20-6), and chemical water properties in the lower Mackenzie River (Project Overview 20-7). A study was recently conducted to review the generation and occurrence of high molecular weight aromatic hydrocarbons from high temperature and pressure environments during oil and gas drilling (Project Overview 20-8). To date, there has been no evidence of in-situ downhole generation of PAHs during a drilling operation.

A number of other research programs related to use of oil-based drilling muds have been completed since the 1986 workshop. These studies have focused on reviewing the options for treatment and disposal of oiled cuttings in the Canadian Arctic (Project Overview 20-2), and developing test protocols for assessing the biodegradabilities of drilling fluid base oils (Project Overview 20-3).

BEMP IMPACT HYPOTHESIS NO. 20

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 20-1

TITLE:	**The Fate of Oil-Based Drilling Muds at Two Artificial Island Sites in the Beaufort Sea**
PRINCIPAL INVESTIGATORS:	P. Erickson, B. Fowler and D.J. Thomas
AFFILIATION:	Seakem Oceanography Ltd.
FUNDING SOURCE:	Environmental Studies Revolving Funds
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

The fate of low aromatic content base oil (Vista ODC) discharged from two artificial island exploratory wellsites in the Beaufort Sea drilled by ESSO Resources Canada Limited was studied over a two-year period. Oiled cuttings were discharged during the winter at both locations.

At Minuk I-53, a sacrificial beach island in 14 m of water, base oil could not be detected in surface sediments outside of an extensive area of grounded ice rubble surrounding the island immediately after drilling prior to ice break-up. Vista oil was widely dispersed in surface sediments at the end of the following open-water season as delineated by a distinctive signature of low molecular weight isoprenoids in the GC trace. Most oil was dispersed from the discharge point (on the west side of the island) in a southerly and then easterly direction (the latter which coincided with the direction of net current flow in the area). Base oil could be reliably quantified more than 900 m to the southeast of the island. The maximum concentration of Vista ODC (defined in terms of the sum of 10 low molecular weight isoprenoid peaks in the GC trace of Vista) in all samples collected was more than 4000 µg/g at a location 350 m to the southeast of the island centre.

Dispersal of oil-based muds appears to be enhanced by the presence of grounded ice rubble near a sacrificial beach island. Grounded ice restricts dispersion in the winter but can carry oiled cuttings long distances from the island after ice breakup. Less than 12% of the oil discharged at Minuk could be accounted for on the basis of the distribution of oil in surface sediments within 1 km of the island centre at the end of one open-water season following the discharge. It is speculated that most of the oil that has been lost was either buried as a result of erosion of the island or was carried beyond the limits of the study area, likely via ice scour and ice transport.

Dispersion was more restricted at Kaubvik I-43, a caisson retained island in 19 m of water. Oiled cuttings were dispersed in an east-west orientation from the discharge point on the south side of the island. Highest concentrations were to the east in the direction of net residual current flow with quantifiable

base oil present more than 400 m in that direction. The maximum concentration of Vista observed was 2000 µg/g. However, less than 2% of the oil discharged at Kaubvik was present in surficial sediments on the basis of contour plots of surface sediment concentrations. It is not known whether the remaining oil is associated with a cuttings pile on the berm slope or whether it was carried away with drifting ice during the early winter. Assuming that the majority of discharged oil is associated with an unsampled cuttings pile, the fate of oiled cuttings discharged from a caisson retained island appears to be governed mainly by currents and in this respect is more typical of conventional drilling platforms in more temperate seas.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this study provide information on the fate of oiled cuttings at two specific locations in the Beaufort Sea under two different discharge regimes - from a caisson retained island and from a sacrificial beach island. In addition, the results demonstrate the usefulness of isoprenoid markers as a tracer of VISTA ODC. Information is also presented in the report that may assist in predicting the nature of hydrocarbon/cuttings accumulation in certain benthic habitats of the Beaufort Sea (Link 2b).

BEMP PROJECT OVERVIEW NO. 20-2

TITLE:	Options for Treatment and Disposal of Oil-based Cuttings in the Canadian Arctic
PRINCIPAL INVESTIGATOR:	R. W. Drinnan
AFFILIATION:	Dobrocky Seatech Ltd.
FUNDING SOURCE:	Environmental Studies Revolving Funds
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

This study reviewed the treatment and disposal options for drill cuttings contaminated with oil-based drilling muds in the Canadian Arctic. Routine solids control equipment, plus 24 additional treatment systems, were considered and the consequences of offshore disposal, onshore disposal and incineration were evaluated for each. The emphasis of the report was on presenting information to assist in decision making by operators and regulatory agencies. Background information on the physical environment, on the environmental effects of oil contaminated cuttings, and on cuttings cleaning technology was reviewed and used as a basis for developing matrices to enable operators to evaluate the engineering, environmental and financial consequences when choosing a treatment system and method of disposal. The acute and chronic toxicities of base oils

and drilling muds were also reviewed.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This report presents some useful information about the performance of various pieces of cuttings cleaning and solids control equipment used in the Beaufort Sea. This information is important when considering the mass loading of oil into the benthic environment and the nature (composition) of post-treated drill cuttings. Such information is essential for calculating mass balances and evaluating the implications of equipment upset conditions on the receiving environment.

BEMP PROJECT OVERVIEW NO. 20-3

TITLE:	**Development of a Test Protocol for Assessing Biodegradabilities of Drilling Fluid Base Oils**
PRINCIPAL INVESTIGATORS:	A.H. Gillam and S.R.T. Severn
AFFILIATION:	CBR International
FUNDING SOURCE:	Panel on Energy Research and Development
EXPECTED COMPLETION DATE:	1989 (Interim Report Phase I, April 1987; Interim Report Phase II, April 1988)
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

It is believed that the most significant environmental effect associated with the discharge of oil-contaminated drill cuttings into the marine environment is organic enrichment. It is important, therefore, to assess the relative biodegradabilities of base oils used in oil-based drilling fluids to be able to assess the magnitude and duration of effects associated with these compounds in the Beaufort Sea benthic environment. This study, currently in the second of three years, is directed at establishing the relative biodegradabilities of a variety of base oils.

A review of biodegradability test protocols indicated that most have been developed for use with soluble substrates in fresh water. The review has also led to the conclusion that a repetitive die away (RDA) or shake flask test are suitable for development of a marine biodegradability test protocol for drilling fluid base oils. In addition, continuous culture techniques appear to be suited to this purpose. A test protocol using a continuous culture with a mixed bacterial population isolated from marine sediments adjacent to the Amauligak development area in the Beaufort Sea is currently being developed.

BEMP IMPACT HYPOTHESIS NO. 20

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this study are relevant to Hypothesis No. 20 because they could provide a practical means of measuring the kinetic aspects of the biodegradability of drilling fluid base oils. This will aid in evaluating the potential environmental consequences of discharging various types of oiled cuttings in specific Beaufort Sea benthic environments by considering the rate at which the oiled cuttings might biodegrade.

BEMP PROJECT OVERVIEW NO. 20-4

TITLE:	**Recommended Laboratory Methods for Assessment of Fish Quality**
PRINCIPAL INVESTIGATOR:	A.D. Woyewoda
AFFILIATION:	Department of Fisheries and Oceans
FUNDING SOURCE:	DFO
COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

This report provides information on standard techniques and procedures for laboratory grading of fish quality to reduce disparity among testing facilities and provide a base from which technical staff and new personnel can obtain standard information.

Twenty-one laboratory procedures for scientific evaluation of fish quality were reviewed and in most cases, tested for applicability to Atlantic species. Each method is described in terms of application, principle of the method, precautions and notes, sample preparation, equipment, reagents, detailed procedure, calculations and typical examples.

Findings of laboratory testing undertaken during the study were incorporated into the report. The methods are not "state-of-the-art" or mechanized but rather use longstanding procedures that may be performed in moderately equipped laboratories. In many cases, newer methods are mentioned. The recommended methods have been tested and used by four DFO regional inspection laboratories and some fisheries institutes in Canada, Norway, Japan, and China. The comments concerning application of these techniques to various quality assessment operations in both research and routine work have been positive.

BEMP IMPACT HYPOTHESIS NO. 20

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is important to Hypothesis No. 20 because it provides information on the art of using an "objective" evaluation protocol in judging the quality of fish tissue in terms of consumer preference and palatability. This issue is related very closely to harvest in Hypothesis 20.

BEMP PROJECT OVERVIEW NO. 20-5

TITLE:	**Assessment of Freshwater Impacts from the Norman Wells Oilfield Development. Part III**
PRINCIPAL INVESTIGATOR:	Blair Humphrey
AFFILIATION:	ESL Environmental Sciences Limited
FUNDING SOURCE:	Environment Canada, NOGAP
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

This project is the third phase of a program to assess freshwater impacts from the Norman Wells Oilfield Development. Phase I addressed the characterization of the crude oil and refinery effluent and included a literature review of the fate and effects of hydrocarbons on the aquatic environment. During Phase II, the chemical characterization of the natural hydrocarbons from seeps was completed. A combination of laboratory and field tests was directed at the lethal and sub-lethal effects of the Norman Wells refinery effluent and of weathered material similar to natural seep hydrocarbons on burbot (Lota lota) and Arctic grayling (Thymalus arcticus). In addition, the water and sediments associated with the exposure tests were characterized and an examination of the effects of ice cover was made. The objectives of Phase III were: (1) to develop a water quality model based on hydrocarbon concentrations measured in the Mackenzie River at locations around Norman Wells; and (2) to determine whether a relationship exists between the health of burbot (Lota lota) or Arctic grayling (Thymalus arcticus) and (a) location of collection or (b) chemical contaminants in the bile, liver and dorsal muscle of the fish.

The study results of Phase III indicated that there were no quantifiable hydrocarbons in the dissolved phase in the water column at quantification levels of about 1 ng L^{-1} for individual compounds. The suspended particulate matter was shown to contain trace levels of PAH, equivalent to about 1 ng L^{-1} of river water. Calculations of refinery effluent input to the Mackenzie River indicate that the maximum hydrocarbon input from the effluent could contaminate approximately 1% of the river at concentrations that could cause sublethal effects on the biota (25 μgL^{-1}). Concentrations greater than 25 ugL^{-1} would

occur over a much smaller proportion of the area of the river. The calculations referred to in the report suggest that at present hydrocarbon input levels, the refinery effluent does not make a significant difference to the hydrocarbon levels which occur naturally in the river.

Chemical and histopathological analysis of burbot collected in the Norman Wells area indicated that no statistical correlation could be made between river quality and chemical or histopathological parameters other than those which are symptomatic of the quality; low quality livers were low in lipid and were small relative to fish size. None of the hydrocarbon indicators such as bile PAH metabolite content correlated with liver quality. Although extreme differences occurred in the quality of livers described in this study, no parameter examined could be implicated as contributing to the quality differences. Other parameters not examined here such as parasitism or stress from other chemical pollutants such as chlorinated hydrocarbons may have an effect, but future research will have to address those areas.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is important to Hypothesis 20 because it provides a perspective on the influence of river-borne hydrocarbons on fish quality (and, therefore, harvest) in the Mackenzie River, which flows into the Mackenzie Delta and nearshore Beaufort Sea. This fact makes it necessary to consider the possible coupling of petroleum-related contaminant effects between river and shelf when it is known that many contaminants found in the Mackenzie River are also found on the Beaufort Shelf and may or may not be from anthropogenic sources.

BEMP PROJECT OVERVIEW NO. 20-6

TITLE:	Studies to Determine Whether the Condition of Fish from the Lower MacKenzie River is Related to Hydrocarbon Exposure
PRINCIPAL INVESTIGATOR:	W.L. Lockhart
AFFILIATION:	DFO, Freshwater Institute, Winnipeg
FUNDING SOURCE:	INAC, NOGAP
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

This study was conducted to investigate two complaints from northern people, mainly those living in Fort Good Hope, related to the quality of fish from the Mackenzie River. Specifically, these complaints were that: (1) burbot livers were reported to have become small and dark in colour to the point that

people would not eat them; and (2) the muscle of whitefish was reported to have become excessively "watery" with the result that these fish were less palatable than in the past. As these complaints began at the same time as the expansion of oil production at Norman Wells, the investigation focussed on examining whether contamination from Norman Wells could be responsible for the deterioration of fish quality.

The main findings of this study were as described below:

(1) Burbot livers were compared among fish collected from several northern communities, Lake Winnipeg, Southern Indian Lake, Manitoba and the Experimental Lakes Area in northwestern Ontario. The occurrence of small dark livers was as severe at Fort Franklin, upstream from Norman Wells, as it was downstream from Norman Wells at Fort Good Hope and Arctic Red River. In addition, small dark livers were found in the burbot from Indian Lake, but absent from burbot from Lake Winnipeg and from the Experimental Lakes Area. This geographical distribution of the occurrence of small dark-coloured burbot livers led the investigators of this study to the conclusion that, if pollution is related to liver condition of burbot, then pollution from Norman Wells cannot be the exclusive cause.

(2) Starvation experiments were conducted with two groups of burbot from Lake Winnipeg. One group received food; the other received none. The liver fats decreased in the starved group of fish, and livers generally became smaller and darker in colour. It was thus demonstrated that the liver condition reported in the Mackenzie River could be produced without pollution by reducing the liver fat, although this can not rule out pollution as an alternate cause of the condition.

(3) Trout were exposed to Norman Wells oil in chronic laboratory experiments. Fish growth was reduced in both length and weight, and the weight/length ratio decreased. This result has been repeated in a number of independent studies with various fish species and types of oil. When length/weight data for fish obtained after the expansion activities at Norman Wells were compared with similar data obtained prior to development at Norman Wells, no difference was evident. Consequently, it appears that even if discharges from Norman Wells have an effect on the growth of fish, it is at a level below the noise of the existing data.

(4) The induction of liver microsomal oxidase enzymes was monitored following experimental treatment of burbot with Norman Wells oil in the laboratory. The induction of these enzymes is a sensitive index of the exposure of fish to petroleum hydrocarbons. There were no significant differences in the induction of these enzymes between fish from Fort Good Hope and those from Lake Winnipeg. This comparison was considered inconclusive because of the higher content of PCBs in Lake Winnipeg burbot, some congeners of which can also induce the target enzyme activities.

(5) Fish from Fort Good Hope and other communities were found to contain low levels of several low-boiling hydrocarbons, notably ethylbenzene and xylenes. These compounds are among the most abundant compounds present in the "water soluble fraction" of Norman Wells Crude and other crude and refined oils. The observation that these hydrocarbons occurred in fish at much higher concentrations in winter, when volatilization was at a minimum, than in summer led the investigators to the conclusion that the river was a source of these materials. As natural oil seeps are common in the river drainage basin, the exact original source of these compounds (i.e., natural or development-related) could not be established.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this study are relevant to the aspect of Hypothesis 20 that links fish quality (harvest/desirability) to hydrocarbon accumulation in tissues. Furthermore, although this study was conducted on freshwater fish distant from the Beaufort Sea, it is relevant to BEMP because of a geographical link - the Mackenzie River discharges to the Beaufort Shelf and characteristics of this water (which flows through areas of natural petroleum seeps and areas where petroleum is produced (principally Norman Wells), whether natural or otherwise must be considered when assessing the possible influence of hydrocarbons on fish harvest in the Beaufort. The above study re-iterated the commonly-held view that the presence of hydrocarbons in fish <u>can</u> affect the quality and palatability of fish. What remains unclear, even with the result of this well conducted study, is whether hydrocarbons from the Norman Wells development actually <u>do</u> affect the quality of fish in the Mackenzie River. The weight of evidence at the present time would suggest that they do not.

BEMP IMPACT HYPOTHESIS NO. 20

BEMP PROJECT OVERVIEW NO. 20-7

TITLE:	**The Flux of Suspended Particulates, Petroleum Related Hydrocarbons, Trace Metals and Nutrients from the Mackenzie River During the Winter Season: A Pilot Study of the East Channel**
PRINCIPAL INVESTIGATOR:	Paul Erickson
AFFILIATION:	Arctic Laboratories Limited
FUNDING SOURCE:	Indian and Northern Affairs Canada
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

The primary objectives of this study were to: (1) provide a time series of measurements of river discharge, sediment discharge and suspended sediment concentrations, and detailed information on suspended particulate grain size distributions characterizing the winter flow regime of the East Channel of the Mackenzie River prior to entry into the Beaufort Sea; (2) provide a concurrent time series of dissolved and particulate petroleum related hydrocarbons, trace metal and nutrient element concentrations; and (3) evaluate the use of a moored in-situ sampler for collecting time-integrated values for metals, hydrocarbons and suspended particulate matter.

Water and suspended particulates were collected through the ice in the East Channel of the Mackenzie River about 30 km upstream from Kittigazuit Bay in April 1985 and early February 1986. In February 1986, samples were also collected in the Main, Middle and Reindeer channels to compare fluxes in the other major channels.

The report presents a comprehensive data set of results for winter chemical water properties in the lower Mackenzie River, a long awaited contribution to describing the chemical characteristics of the river. Data are presented for (1) dissolved non-polar and aromatic hydrocarbons; (2) chlorinated hydrocarbons, Cu, Cd, As, Hg, Pb, V, Zn, Cr and Ni in the dissolved and particulate phases; (3) dissolved nitrate, silicate and orthophosphate; and (4) particulate organic carbon/particulate organic nitrogen.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

A critical aspect of evaluating the possible environmental implications of drilling operations and the disposal of drill cuttings in the nearshore areas of the Beaufort Sea is consideration of the natural processes occurring in these areas. This report provides much needed information on the flux of metals, hydrocarbons and particulates to the Mackenzie Delta area. These data will allow

a more realistic evaluation of the relative scales of possible development/ industrial inputs and natural loading of contaminant chemical species.

BEMP PROJECT OVERVIEW NO. 20-8

TITLE:	A Review of the Generation and Occurrence of High Molecular Weight Aromatic Hydrocarbons from High Temperature and Pressure Environments During Oil and Gas Drilling
PRINCIPAL INVESTIGATORS:	A.H. Gillam and G.G. Cross
AFFILIATION:	CBR International
FUNDING SOURCE:	Indian and Northern Affairs Canada
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NO.:	20

BRIEF PROJECT DESCRIPTION

This study was conducted to document the in-situ downhole production of polyaromatic hydrocarbons (PAH) during rotary drilling operations. This situation was raised as a theoretical possibility at the 1986 BEMP workshop, where it was noted that the temperatures and pressures commonly encountered downhole at metal surfaces in the presence of hydrocarbons (either from the formation or from drilling mud and mud additives) were conducive to in-situ PAH production. It was further noted at the 1986 workshop that the in-situ downhole production of PAH had been suspected during drilling in 1985 on the Scotian Shelf.

The literature reviewed in the report indicated that production of PAHs was unlikely under downhole temperature, pressure and friction regimes typically encountered in offshore drilling. It was suggested, however, that at elevated temperatures in a reducing environment (sometimes encountered in drilling operations) the production of small quantities of PAH compounds is theoretically possible when free radical intermediates formed under the above conditions from complex organic molecules re-combine to form aromatic compounds, including PAHs. Polymerisation of dienes, via cyclization and dehydrogenation, is also theoretically possible under downhole conditions.

The main findings of the study were:

(1) the literature searches failed to reveal any documented evidence for the downhole generation of PAHs during a drilling operation;

(2) a survey of European and North American oil industry groups and offshore drilling practitioners failed to provide any documented evidence in either Europe or North America for the production of PAH

as the result of pressure, temperature and friction regimes at the drill bit when using lower toxicity oil-based mud; and

(3) detailed examination of the aromatic hydrocarbon data for cuttings sampled during the 1985 East Coast OBM Monitoring Program could not confirm a reservoir source of the PAHs. The major source of PAH in these cuttings was concluded to be the drilling fluid base oil followed by drilling fluid additives (such as lubricants, emulsifiers/surfactants, shale control inhibitors (water-base muds), filtrate reducers and thinners/dispersants) used in the drilling program.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

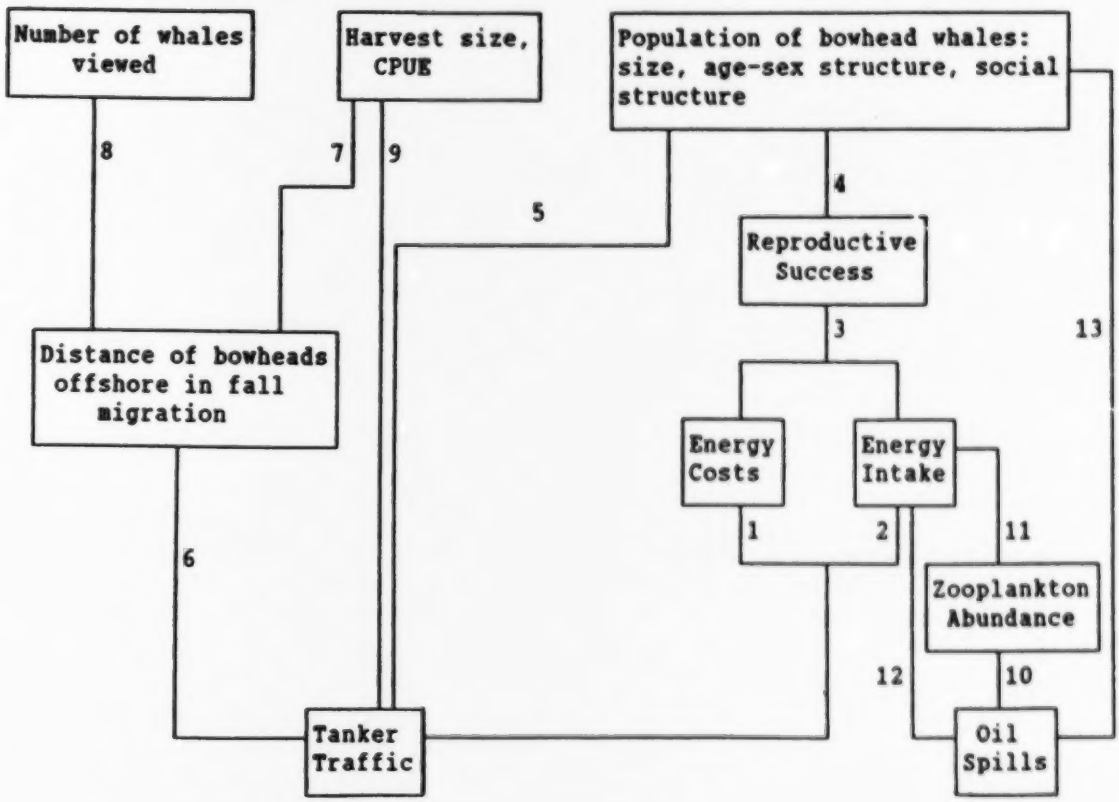
This study has presented evidence that downhole (in-situ) generation of PAHs is an unlikely source of PAH in rotary drilling operations. Consequently, this is not an area of concern for drilling operations.

HYPOTHESIS NO. 21

Tanker traffic and minor oil spills associated with the westward transport of Canadian Beaufort oil will cause reductions in the western Arctic population of bowhead whales and the harvest of this population by Alaskan Inupiat.

FIGURE 21-1

POTENTIAL EFFECTS OF WESTWARD TRANSPORT OF OIL BY TANKER ON BOWHEAD WHALES



BEMP IMPACT HYPOTHESIS NO. 21

Linkages

1. Tanker traffic will affect the energy balance of whales by increasing the amount of energy expended over the course of a year.

2. Tanker traffic will lead to a reduction in the energy intake of bowheads by reducing the time available for feeding.

3. The energy balance of a bowhead whale determines its survival and its ability to reproduce.

4. A decrease in reproductive success will lead to a reduction in population size.

5. Tanker traffic will affect the bowhead population through direct mortality, disruption of social behaviour, and separation of cows and calves.

6. Tanker traffic will cause a long-term offshore displacement of the fall migration of bowheads off Alaska.

7. Offshore displacement of the bowhead migration will cause a reduction in the harvest size and catch per unit effort (CPUE) in the fall hunt of bowheads by Alaskan Inupiat.

8. Offshore displacement of the bowhead migration will cause a reduction in the number of whales that can be viewed from shore.

9. Tanker traffic will be perceived by Alaskan Inupiat whalers to have a negative effect on the success of the fall hunt for bowheads.

10. Oil spills associated with tanker loading and unloading will reduce zooplankton abundance.

11. Reduced zooplankton abundance will decrease the energy intake of bowhead whales.

12. Oil spills will decrease the ability of bowhead whales to feed.

13. Oil spills related to tanker transport will directly reduce the size of the bowhead whale population.

BEMP IMPACT HYPOTHESIS NO. 21

STATUS OF KNOWLEDGE REGARDING HYPOTHESIS NO. 21

Hypothesis No. 21 was developed and evaluated during the 1986 workshop. The workshop participants concluded that this new hypothesis was valid, but most of its linkages were unlikely to occur at the level of shipping activity examined during the meeting (16 round trips between August 1 and 31 October each year). Further testing of the hypothesis was considered unjustified, and no field research or monitoring programs were recommended. However, the group did suggest the need for re-analysis of existing data to determine the probability and possible significance of concerns reflected in three of the hypothesis links, and that efforts be taken to mitigate impacts of tanker traffic on the success of the fall bowhead hunt in Alaska.

REVIEW OF RECENT AND ONGOING RESEARCH PROGRAMS

BEMP PROJECT OVERVIEW NO. 21-1

TITLE:	**The Potential Effects of Tanker Traffic on the Bowhead Whale in the Beaufort Sea**
PRINCIPAL INVESTIGATORS:	W.R. Koski, G.W. Miller and R.A. Davis
AFFILIATION:	LGL Limited environmental research associates
FUNDING SOURCE:	Indian and Northern Affairs Canada
EXPECTED COMPLETION DATE:	1988
RELEVANT BEMP HYPOTHESIS:	21

BRIEF PROJECT DESCRIPTION

Since 1980, the U.S. and Canadian governments (Minerals Management Service and Indian and Northern Affairs Canada) and the oil industry of both countries have funded numerous studies to investigate the potential effects of industrial activities on bowhead whales in the Beaufort Sea. In addition, several studies on the reproductive biology and population size of bowheads have also been undertaken to evaluate and support the subsistence harvest by Alaskan Inupiat. The primary purpose of the present study was to integrate the large volume of data that have been collected through these programs to examine a series of questions related to the possible effects of production and transportation of oil and gas from the Canadian Beaufort Sea. Many of the issues addressed in this study are related to questions and concerns identified during the 1986/87 BEMP workshop. The following summarizes the principal findings of the study (taken from Koski et al. 1988).

BEMP IMPACT HYPOTHESIS NO. 21

Distribution of Calves

- Tanker traffic along the proposed route extending west from the Amauligak would have influenced large numbers of bowhead calves only in one summer (1982) of the seven years for which data is available.

- Cows and calves migrate through the Alaskan Beaufort Sea primarily in late September, but are relatively widespread through nearshore and offshore waters at that time. Concentrations of calves are uncommon.

Age Segregation

- There was some evidence that age segregation occurred on the summering grounds. Waters west of Amauligak are occupied in August and September of most years by the small and medium subadult component of the population.

- In some years (e.g., 1985), virtually the entire subadult component of the population would be exposed to ship noise from the proposed tanker traffic.

- In most years, few summering adults would be exposed to ship noise since they occur farther east and offshore. However, adults would have been affected by tanker traffic noise in 1982 and during fall migration off the Yukon and Alaskan coasts.

Effects of Age on Bowhead Behaviour

- Behaviour of bowheads in deep water was statistically different than in shallow water, and older larger whales tended to occur in the deeper water. Any study of the effects of tanker traffic on whale behaviour must account for water depth and, probably, whale size (age).

Micro-scale Movements

- Analysis of the location of whales rephotographed on the same day showed that undisturbed whales moved at an average rate of about 2 km/h. Studies on the response of whales to disturbances of tanker traffic should therefore account for these natural local movement patterns.

Site Fidelity within a Season

- Whales tend to remain within a particular zone while on summering grounds. Net rates of movement averaged 5.9 km/d for the 96 pairs of between-day resightings.

BEMP IMPACT HYPOTHESIS NO. 21

- Whales that summer in areas traversed by the tanker route are likely to be exposed to ship noise on several occasions during the summer. Individuals to the north and east would remain free of disturbance except during their fall migrations.

- There was little evidence that individual whales associated with each other for extended periods (i.e., several days).

Between-year Site Fidelity

- There was some evidence that adult whales that fed in the Franklin Bay area tended to return to this region each year. Therefore, this component of the population would not be exposed to ship traffic.

- The subadult component that summers along the Yukon coast and the edge of the Mackenzie plume would be subject to repeated disturbances by tanker traffic over a number of years since these individuals tend to return to this region.

Known Effects of Ship Traffic

- Bowheads exhibit overt behaviour in response to approaching ships at distances of 1-7 km. This disturbance is manifested in displacement activity, where bowheads seem to move up to 6 km away. These movements can take from 0.5 to 2.0 hours and are made at a rate of 3-10 km/h. In the absence of a disturbance, bowheads normally move at an average rate of 2 km/h.

Separation of Cow-Calf Pairs

- Based on a modelling exercise involving data on whale response criteria, whale calls, ship noise, transmission loss and ambient noise, it was shown that permanent separation of cow and calves is very unlikely.

Interference with Bowhead Movements

- On most passages, tanker traffic would not interfere with the coastal harvest of bowhead whales in fall. However, increased hunting success may result in some cases when ice forces ships to pass within 20-40 km of shore causing the whales to move into nearshore hunting areas.

- On rare occasions, tankers may travel closer than 20 km from shore and cause a negative impact on the hunt. However, it is not possible to determine at which distance this would occur.

BEMP IMPACT HYPOTHESIS NO. 21

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study specifically addresses those linkages of Hypothesis No. 21 that link tanker traffic associated with the westward transport of oil to reductions in the western Arctic population of bowheads and the harvest of this population by Alaskan Inupiat. Through analysis of the available data collected during numerous investigations conducted since 1980, this study has provided information with which to re-assess the validity of linkages 5, 6, and 7.

During the 1986/87 BEMP workshop, it was concluded that tanker traffic was unlikely to affect the bowhead population through direct mortality, disruption of social behaviour or cow-calf separation (Link 5). However, it was considered worthwhile to examine hypothetical situations where a cow and calf would be permanently separated as a result of avoidance responses to approaching tankers and the inability to maintain vocal contact. The modelling exercise indicated that cow-calf pairs are very unlikely to become permanently separated as a result of a passing tanker or ship. Although a whale could be displaced by as much as 6 km and cow and calf separation could be as much as 12 km if movement was in opposite directions, received levels of loud bowhead calls at this distance would be well above median ambient levels once the ship had passed. The cow and calf should have no difficulty re-establishing contact with one another at this time.

Concern was also expressed by the workshop participants that tanker passage would cause a seaward displacement of the bowhead migration along the Alaskan coast, which would reduce the size or ease of the Alaskan Inupiat whale hunt in autumn. While it was agreed that offshore displacement of the migration would cause a reduction in the harvest size and catch per unit effort (CPUE) of the hunt (Link 7), long-term offshore displacement of bowheads off Alaska was considered unlikely to occur (Link 6). The present study provides information in support of this conclusion. On most passages, the tanker would not pass within 40 km of shore off Kaktovik and therefore would not affect the number of huntable whales. On those passages where a tanker passes between 20 and 40 km of shore, it is likely that some bowheads will be displaced southward closer to the whalers. It was considered unlikely that a tanker would travel close enough to shore to force even the nearshore whales to be displaced offshore.

RECENT AND ONGOING RESEARCH PROGRAMS OF GENERAL INTEREST TO BEMP

BEMP PROJECT OVERVIEW NO. G-1

TITLE:	Arctic Char Stock Separation
PRINCIPAL INVESTIGATORS:	J. Reist
AFFILIATION:	Dept. of Fisheries and Oceans, Freshwater Institute
FUNDING SOURCE:	DFO, Fisheries Joint Management Committee
RELEVANT BEMP HYPOTHESIS NO.:	Of general interest

BRIEF PROJECT DESCRIPTION

This study was initiated in 1986 to assess the presence and geographic limits of genetic stocks of Arctic char in the western Arctic. The nature of the study is similar to that being conducted for broad whitefish in the lower Mackenzie River (NOGAP Program B.3). Its major objectives are to: (1) determine the discreteness and number of Arctic char stocks through morphometric, meristic and electrophoretic techniques and (2) establish the relatedness of these populations.

In late August and September 1986, Arctic char were sampled at 6 sites on Joe and Cache creeks and Firth, Babbage, Canoe and Rat rivers. Preliminary results of this work indicate that Yukon North Slope char are structured into distinct genetic stocks on similar bases as Mackenzie River broad whitefish (see Project Overview 14-4). Specifically, there appears to be 4 distinct genetic stocks that correspond to the major drainages in the area (Rat, Big Fish, Babbage and Firth). In addition, it is considered likely that stocks within major tributaries of these systems also constitute separate stocks. However, further investigations are required to confirm this.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

In the event that the hydrocarbon development scenario for the Beaufort region changes such that new impact hypotheses for Arctic char need to be formulated, this information will be important for assessing the possible effects of development activities on this species. Genetic structuring has profound implications on planning for mitigation of environmental impacts, as well as fisheries management. This information will allow Arctic char populations within the region to be managed on a stock-specific basis, which will ensure that each genetic population is maintained.

BEMP PROJECT OVERVIEW NO. G-2

TITLE:	Enumeration of the 1987 Upstream Migration of Arctic Char (*Salvelinus alpinus* L.) in the Big Fish River, N.W.T.
PRINCIPAL INVESTIGATORS:	D.S. MacDonell
AFFILIATION:	North/South Consultants Inc.
FUNDING SOURCE:	Fisheries Joint Management Committee
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	Of general interest

BRIEF PROJECT DESCRIPTION

In response to concerns that the Arctic char population in Big Fish River, N.W.T. was continuing to decline under the reduced fishing pressure of recent years, the Fisheries Joint Management Committee (JFMC) and Department of Fisheries and Oceans closed the river to all fishing during the summer of 1987. To address uncertainties regarding the status of this population, the FJMC initiated a study to assess the upstream migration of Arctic char during 1987. The primary objectives of the study were to: (1) obtain a direct count of char migrants using a weir; and (2) conduct a simultaneous Schaefer stratified population estimate and determine its efficiency for use in enumerating char in other systems. The Petersen method was considered as a contingency to estimate the number of char on overwintering grounds.

Field work was carried out in Big Fish River during August and September, 1987. Population estimates obtained from the Petersen method indicated that the Arctic char population in Big Fish River has declined 25-50 % over the last 15 years, based on previous Petersen estimates of 12,000 - 17,000 char (Stein et al. 1973). However, due to the relatively high proportion of spawners in the population compared to other stocks in the region, it appears that this stock could recover relatively quickly. As much as 17% of the total population in Big Fish River were current-year spawners.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

In the event that the hydrocarbon development scenario for the Beaufort region changes such that new impact hypotheses need to be formulated for Arctic char, information on the abundance and distribution of populations within the region will be important to assess the possible effects of development activities on this species, particularly in coastal areas.

RESEARCH PROJECTS OF GENERAL INTEREST TO BEMP

BEMP PROJECT OVERVIEW NO. G-3

TITLE:	**Enumeration of the 1986 Upstream Migration of Arctic Char in the Hornaday River, N.W.T.**
PRINCIPAL INVESTIGATORS:	D.S. MacDonell
AFFILIATION:	North/South Consultants Inc.
FUNDING SOURCE:	DFO, Economic Development and Tourism Branch of GNWT, Fisheries Joint Management Committee
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	Of general interest

BRIEF PROJECT DESCRIPTION

Concerns over reduced catches of Arctic char in the Hornaday River, N.W.T. and increased market demands for these fish in Inuvik prompted initiation of this study. The major objectives of the study were to: (1) conduct a total assessment of the upstream migration of char to determine whether quotas could be increased; and (2) evaluate the feasibility of using a weir to capture char for commercial harvest on the Hornaday River.

During the fall of 1986, the upstream migration of Arctic char in Hornaday River was enumerated by means of a conduit weir. A total of 10,800 char were counted during the study, with a high daily count of about 1570 fish. The char were found to be relatively small and young. Low mean age, mean length, catch per unit effort (CPUE) and total counts suggested that this population has been heavily exploited by the commercial and subsistence fisheries at this location.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study provides basic information on the relative abundance of Arctic char in the Hornaday River during fall migration. In the event that the hydrocarbon development scenario for the Beaufort region changes such that new impact hypotheses need to be formulated for Arctic char, information on the abundance and distribution of populations within the region will be important to assess the possible effects of development activities on this species, particularly in coastal areas.

BEMP PROJECT OVERVIEW NO. G-4

TITLE:	**Monitoring of Domestic/Commercial Fisheries for Arctic Char in the Big Fish River and Rat River Areas, N.W.T., 1986**
PRINCIPAL INVESTIGATORS:	P.D. Sparling and D.B. Stewart
AFFILIATION:	Arctic Biological Consultants
FUNDING SOURCE:	DFO, Fisheries Joint Management Committee
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	Of general interest

BRIEF PROJECT DESCRIPTION

Domestic and commercial fishing for Arctic char in the western region of the Mackenzie Delta takes place as char migrate upstream through the delta to spawning and overwintering grounds on tributaries of the Rat and Big Fish rivers. In response to community concerns, DFO initiated a series of studies in 1983 to assess the abundance and distribution of Arctic char stocks in the region. A survey of the domestic and commercial fisheries was carried out during August and September, 1986. The area surveyed extended from Fort MacPherson, north along the western edge of the delta to Shingle Point on the Beaufort Sea coast.

A total of 1300 Arctic char were taken during the fall gillnet fishery, while 1660 char were taken during the winter fishery in Cache Creek. The condition of these fish (incidence of parasites, reproductive condition) was noted, and length and weight measurements were taken.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

In the event that the hydrocarbon development scenario for the Beaufort region changes such that new impact hypotheses need to be formulated for Arctic char, information on the abundance and distribution of populations within the region will be important to assess the possible effects of development activities on this species, particularly in coastal areas.

BEMP PROJECT OVERVIEW NO. G-5

TITLE:	**Domestic Fishery in the Mackenzie Delta Area**
PRINCIPAL INVESTIGATORS:	P.D. Sparling and J.Y. Sparling
AFFILIATION:	P. Sparling Consultants
FUNDING SOURCE:	Fisheries Joint Management Committee
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	Of general interest

BRIEF PROJECT DESCRIPTION

A survey was conducted from June through November 1981 to assess domestic fishing effort and harvest in the Mackenzie Delta region. Data were obtained through interviews with domestic fishermen, and enumeration and biological sampling of fish from gillnet catches. Catch-effort determinations were made for each fish species, which included broad whitefish, lake whitefish, Arctic cisco, least cisco, inconnu, Arctic char, lake trout, northern pike and burbot. Results of this survey are presented in a discussion paper prepared for the Fisheries Joint Management Committee (Sparling and Sparling 1988).

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this study provide basic information on the occurrence and predominance (relative to the gear type and size used) of fish species in the Mackenzie Delta region at certain times of the year. Information specific to fish species considered as VECs is relevant to those impact hypotheses that link development activities with potential effects on fish resources in the region.

BEMP PROJECT OVERVIEW NO. G-6

TITLE:	Arctic Industrial Activities Compilation: Volume 3 - Canadian Beaufort Sea; Seismic and sounding surveys, vessel movements, helicopter traffic, and site-specific activities, 1980 to 1986.
PRINCIPAL INVESTIGATORS:	P. Brower[1], J.W. McDonald[1], W.J. Richardson[2], and R.A. Davis[2]
AFFILIATION:	ESL Environmental Sciences Limited[1] and LGL Limited[2]
FUNDING SOURCE:	Department of Indian and Northern Affairs and Northern Development and Department of Fisheries and Oceans
EXPECTED COMPLETION DATE:	Completed
RELEVANT BEMP HYPOTHESIS NO.:	Of general interest

BRIEF PROJECT DESCRIPTION

Most industrial activities in the Beaufort Sea region are directly or indirectly associated with the search for oil and gas. Activities in marine areas include dredging, drilling, seismic and sounding surveys, island/camp maintenance, vessel movements, helicopter and fixed-wing flights, and ice-breaking.

Information on seismic and sounding surveys, vessel movements, site-specific activities, and helicopter flights in the Canadian Beaufort Sea from 1980 to 1986 are summarized in this volume. The data for each type of activity have been compiled, standardized and entered into a DBase III+ database. A complete copy of the database has been archived at the Institute of Ocean Sciences, Patricia Bay, B.C. Maps showing temporal and spatial variations for each activity category are provided in the report, and annual summaries are provided for the seven years of activities. For the 1980-84 period, activities were summarized only for the August 1 - September 10 period. For 1985 and 1986, the time frame of the study was expanded to include the period from June 1 to December 31. The spatial boundaries of the study are west to longitude 141°W (Alaskan-Yukon border), east to longitude 127°W, north to latitude 72°N, and south to latitude 68°30'N.

The level of industrial activities increased yearly from 1980 to 1983, peaked in 1984 and 1985, and then sharply declined in 1986, mainly because of the dramatic drop in the world price of oil. The centre of the main industrial zone remained relatively constant form 1980 to 1986.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This research provides the most current summary of major industrial activities that occurred in the Canadian Beaufort Sea during the period from 1980 to 1986. It is considered relevant to all of the BEMP hypotheses because it defines the zone of activity in the region and provides the historical information necessary to evaluate the potential impacts of the various types of activities on the biophysical environment.